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THE CHEAPEST POINT OF CUT-OFF.

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In reply to Professor De Volson Wood's criticisms on what I have had to say regarding economy of steam, I will compare only what Prof. Wood has written with what I have written.

In this JOURNAL, January, 1884, Prof. Wood says:

"It is proper to observe that in Prof. Marks' analysis of this problem in the last December number of this JOURNAL, that the constant charges are assumed to be a constant fraction of the cost of steam;" also, "The solution then is not general but *special*, and we may draw the inference that the point of cheapest cut-off is *generally* dependent upon the constant charges."

Prof. Wood does not sustain the first statement or even refer to it in his last paper.

Is this fair? One of us was wrong. Which is it?

In this JOURNAL for February, 1884, I say:

"The question squarely at issue between myself and my critics is this:

"*Do the constant charges have the effect of making the cheapest point of cut-off later than it would appear to be from a purely physical consideration?*

"I have asserted, and believe I have proved, that they do not. I

would further add that I am convinced that the ratio existing between the actual steam from boiler and the steam by the indicator diagram in no wise affects this question.

"More knowledge of the law of this ratio may affect the point of cut-off, but will not involve the constant charges."

May I beg the reader to mark this statement? It is all that is at issue, and other questions that may be raised are not pertinent to the point at issue.

Prof. Wood says that there is a difference between the "designer's problem" and the "owner's problem." I do not recognize such a distinction. The first problem, the problem which I have essayed to solve, is how to get a certain horse-power with the least possible expense. There is another problem, which is, how to make the best of an existing plant which is not adapted to the requirements of its work, but this is a *special* problem, requiring a special knowledge of the existing machinery, and cannot be treated generally.

In this JOURNAL for December, 1883, I say:

"The gain by increasing the expansion from eight to nine times is but a theoretical one per cent. at the outside, and possibly there is an actual loss.

"The theoretical minimum results for condensing trials are not closely calculated because they do not surely indicate accurate attainable results, but serve merely to show in what direction progress must be made.

"Right here our knowledge is deficient, and we must have more data regarding condensation before attempting to accurately predict real results at high expansions.

"Concentration of power is lost with increasing economy of steam. It is a very important attribute of the steam engine, bearing directly upon its efficiency as a machine."

Right in the face of these statements Prof. Wood attributes to me the following ideas:

"The problem before us, then, is the *designer's* problem, and not the *owner's* problem.* John Doe having confidence in the Professor,

* The *designer's* problem consists in making an engine which will deliver a given number of horse-powers most economically; the *owner's* problem consists in delivering the greatest number of horse-powers from a given plant with the most profit to the owner. When the designer has properly solved his problem, it is merged into that of the owner's.

secures his services in selecting the engine which will be the most economical for delivering 150 horse-powers for ten years. From the known initial pressure (say 90 pounds), the back pressure (say 5 pounds), and the clearance (which he assumes to be small), he finds by means of equation (8)

$$e = \frac{B}{P_b} = \frac{5}{90} = \frac{1}{18},$$

for the approximate value of the cut-off; and for a more accurate value

$$e = \frac{B\left[1 - b\left(1 - \log_{\cdot}\frac{b}{k}\right)\right]}{P_b} + k - b\frac{B}{P_b}\log_{\cdot}\frac{1}{e}, \qquad (7)$$

which for want of data we cannot reduce numerically, and hence will assume it as $\frac{1}{17}$, or even $\frac{1}{16}$. These men go into the market, and with the given data, the Professor selects the engine that will produce the 150 horse-powers "*by using the least possible steam per horse-power per hour;*" excepting that, for commercial reasons, he quietly uses a cut-off of $\frac{1}{16}$* as the basis of selection."

The whole problem is a "commercial" problem. I do not reduce the number of expansions because of the *constant charges*, as might be inferred from Professor Wood's language, but for the reasons quoted above.

Is Prof. Wood fair in ignoring a limitation to expansion of steam which I mathematically deduced from physical data, and then stated in plain English?

He has no right to attribute to me absurdities in the way of $\frac{1}{16}$ or $\frac{1}{17}$ cut off under conditions less favorable to extreme expansions than the conditions from which I deduced a limit of 8 or 9 expansions.

In this JOURNAL, February, 1884, I say:

"Reference to my paper will make it clear, I trust, as to how the point of cut-off affects the weight of steam per horse-power per hour, and also fix the limits within which physical laws confine the expansion of steam."

Professor Wood writes as follows:

"*Doe.* The question of the cut-off grows in interest. I see our Professor says: 'The point of cut-off has, practically, nothing to do with the constant charges, save so far as it determines the volume of the cylinder required.'

* JOURNAL FRANKLIN INSTITUTE, Dec., 1883, and Jan., 1884, p. 41.

"*Smith.* I do not presume to understand all that is written about the cut-off; but there is something amusing in this statement of the Professor. As before, he denies one proposition, and then, in my opinion, admits another element which opposes his denial; for in my opinion, the size of the cylinder, involving as it does the cost of the engine, does affect the economical point of cut-off by making the constant charges, so called, different from what they otherwise would be; for the truth of which I appeal to you in the case of the two engines now before you. The consideration of the theoretical effect of constant charges, I leave to the Professor."

The constant charges are:

(1) Interest on deterioration of and repairs to engine.
(2) Wages of fireman and engineer.
(3) Cost of oil and waste.
(4) Interest on deterioration of and repairs to boilers.
(5) " " " shelter.
(6) Taxes and insurance on machinery and buildings.

Of all these different items there is but one that is a function of the size of the cylinder; it is the interest on deterioration of and repairs to the steam cylinder. I will even say; although it is *not correct;* for the sake of having the same premise in our argument, the interest on deterioration of and repairs to the *engine.* What does it amount to? Are our brethren, the marine engineers of England, a set of dolts, who have made their ship owners rich by piling cylinder on cylinder, and carrying the expansion of steam to its utmost physical limitations in cylinder after cylinder?

Could anything be more unfair than to endeavor to make me acknowledge in his dialogue the difference in interest on the cost of the steam cylinders, or even of the engine, as the controlling element of cost in the constant charges? It is a trifle not worth noticing, and all experience has so proved it. Surely that engine requiring the least steam per horse-power per hour demands the least cost for boilers and appurtenances.

Will Prof. Wood be so good as to give some actual case in place of the subjoined paragraph?

"*Doe.* Not necessarily so, for it might be *economy* to *lose* on the fuel and save the cost of enlargement. Suppose that the interest, repairs, etc.—"constant charges"—are 16 per cent. on this purchase, I would

save $160 per year if the smaller engine will answer. If my boilers are somewhat under size, perhaps $50 per year extra in fuel will supply the steam, in which case there will be a decided saving. Please examine these specifications of my boilers and inform me if they have sufficient capacity for the smaller engine."

Professor (after figuring). They will answer.

Doe. The boilers being out of the question, does it not follow, from your own reasoning, that it may, and probably will, be more economical for me to purchase the smaller engine.

Professor. Well, it appears so; but I still assure you that *the larger engine will give you the* 150 *horse-powers with less cost for fuel than the smaller one.*

Will Prof. Wood be so fair as to take the ordinary case where the boilers are in question?

Does Prof. Wood mean to imply that the experimental figures for weight of steam given by the Buckeye Engine Company, or by Mr. Barrus, are a result of the constant charges?

Professor Wood should remember that his thesis is "the point of cheapest cut-off is *generally* dependent upon the constant charges."

I do not dispute the accuracy of the physical constants obtained by Mr. Thompson and Mr. Barrus; they are valuable additions to our experimental physical knowledge and will be more valuable when we know the size of cylinder, the number of strokes, the quality, temperature and pressure of the steam, and whether the engines were condensing or non-condensing. Professor Wood writes as follows:

"It is unnecessary to argue this point; it is only necessary to convince you that these so-called "constant charges" are variables in the process of designing, to cause you to abandon your rule, giving as it does a cut-off of $\frac{1}{10}$ to $\frac{1}{20}$, which you have insisted up to the present time to be "practically accurate within the widest range," after establishing certain relations in regard to the steam. (Jan., 1884, p. 1.)"

I say, January, 1884, JOURNAL OF THE FRANKLIN INSTITUTE:

"What is needed to render this rule *practically accurate within the widest range*, is to establish the ratio which exists between the steam furnished by the boiler and that recorded by the indicator diagram, under all the various conditions as to initial and back pressures, and points of cut-off used."

Could what I said as a qualification be more garbled?

In this JOURNAL for February, 1884, I wrote as follows:

"The proportion from which equation (5) is derived is this:

"cV: eV:: constant charges per day (C); cost of steam per day for a cut-off, e, and a given horse-power.

"c is not a constant, as stated by Prof. Wood, nor is it said to be a constant in my paper; it is a function of the mean effective pressure.

"If fallacy there be in what I have written, it must be found in the above proportion.

"The mere assertion of so distinguished a mathematician as Prof. Wood carries so much weight that it is a duty which he owes to himself and to the writer to give the most careful consideration to the point at issue, and either prove the writer's error unmistakably, or to fairly acknowledge his own, in as public a manner as he has seen fit to publish his condemnation.

"It is a question that not only involves himself, but also all his colleagues giving instruction in engineering in the Stevens Institute."

Has Professor Wood referred to equation (5) in his last paper after criticizing it so severely in his first paper? Has Professor Wood been just in avoiding an acknowledgment of his own mathematical blunder?

I have endeavored to meet every important scientific point raised in Professor Wood's paper by reference to, and quotation of, published statements.

If I have omitted any which Professor Wood deems important I shall be pleased to discuss them at length if he will be so good as to direct my attention to them. I confess I have been considerably at a loss to comprehend why Professor Wood should have adopted the platonic literary style of his last paper. Unless because it affords him a convenient method of making his opponent say that which he desires to have him say, and thus expose himself to mis-construction and criticism. If he will be kind enough not to speak for me but directly for himself I will be pleased to treat the scientific discussion soberly and fairly and himself courteously.

I see no reason to alter the following statements. JOUR. FRANK. INST., February, 1884:

"*In other words, John Doe must determine the most economical point of cut-off for his particular case from purely physical considerations, and then, if he can, buy an engine which will do his work with that cut-off with the least amount of constant charges.*

"*He will be wiser if he anticipates an increase of business to choose a cut-off a little too early rather than too late for greatest economy.*"

"This same point was mathematically stated in my letter of Oct. 20, 1883, to the *The American Engineer*, with the remark: 'If I am correct in my premises, the method of Professor Rankine, as well as the papers of Messrs. Wolff, Denton and Weightman, and of Professor Thurston must be valueless.' There has been no proof, of any practical value, given to the contrary of this assertion, or of my original position in this Journal, June, 1880, save such limitations as I have myself established December, 1883."

"*In either case, John Doe's only opportunity to save money lies in saving steam per horse-power per hour*, and the greater the power used the more money he can save by proper attention to the point of cut-off. It is right here that these gentlemen—Professors De Volson Wood and Thurston, and Messrs. Wolff, Denton and Weightman—have deceived themselves, and perpetrated the absurdity of saying that you can save money by using more steam than is really necessary to do the work demanded."

In the preceding discussion I have in fairness to Professor Wood confined myself to my published papers anterior to March, 1884. Since that time [JOUR. FRANK. INST., March and April, 1884] I have published a paper on "Initial Condensation" which possibly may throw more light on the law of the condensation of steam inside of the steam cylinder.

These papers have, in a collected form, been for some time in Professor Wood's possession, and I am justified in assuming that he permits his present critique to be published with a full knowledge of what I have written, since he has done me the honor to criticise my earlier writings.

I will end this argument by saying, that acceptance of authority, however high, makes an end of scientific progress.

Rankine's genius enabled him to step from peak to peak of knowledge leaving us to toil through the dark valleys between as best we may. Is it not possible however that the very rapidity of his progress has caused him to overlook important conditions and limitations of the principles which he enunciated in rapid succession? May it not be that his delighted and dazzled followers have not been as circumspect as they would be under different circumstances, or in accepting the authority of a less brilliant leader?

Nature is no shallow fountain to be exhausted in any direction by the most profound of her students, and each new discovery but opens new vistas into the infinite field of knowledge that lies before us.

Nor do I wish to be understood as failing to render to Professors Thurston and Wood that tribute of gratitude and admiration which is due to them from all engineers. Their talent, their industry, and their wide and varied knowledge, has been known for a score of years, and they have been foremost in the advancement of the standing of the engineering profession in many ways. No denial of mine, did I desire to make such denial, would detract from their well-earned right to the title of leaders in engineering research.

Criticism which I have been forced to make of the writings of these gentlemen has ever been in self defense. I would gladly have gone my own ways and left them unmolested, however much my opinion or my deductions might have differed from theirs. My language has been positive because the laws of nature are precise. I cannot follow them and evade plainness of speech.

Taking Professor Wood's article as the work of a professor not applying himself as an investigator of natural laws, but as the act of an advocate, I cannot deny his ability as a dialectician. Professor Wood is, however, incapable of not perceiving what lies beneath his argument, or of overlooking many points that he has not noticed. While he is thus intellectually incapable of not perceiving his suppression of half the truth and his zig-zag evasion of difficulties, maybe he regards his course as a subdivision of labor in the cause of truth and thus justifies it?

The ardor of a friend too may plead his defense for having overleaped the bounds of natural laws, and forgotten the philosophic circumspection of a scientific investigator.

No word of doubt or hesitation mars Professor Wood's appeal to popular sentiment and no one knows the efficiency of this course better than himself. He represents matters of opinion as undoubted truth, and he neglects undoubted truths where not suitable to his purpose. Is his paper worthy of himself or of a place in the first rank of authority?

In order not to misrepresent Professor Thurston's attitude in the present discussion, it is but right to quote his words in a letter to the writer, April 16, 1884, regarding initial condensation.

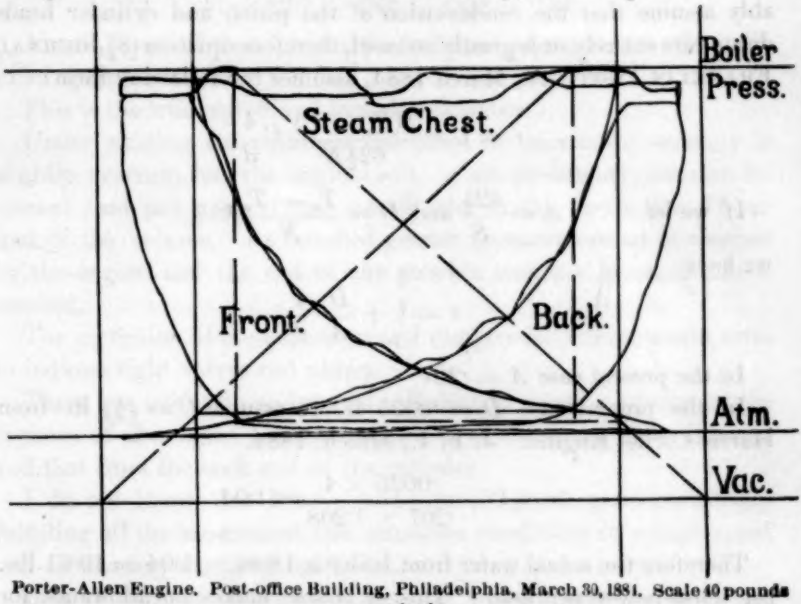
"If it should prove that the functions are of the form you have assumed you will have earned the credit of their first publication. In any event you have been the first to indicate plainly the correct method of seeking the needed quantities, and to make an effort to obtain the

coefficients in a correct manner, for I intentionally left it indefinite in my papers. I shall hope before the summer is over to get at the real thing approximately if not exactly."

It would be hard to over-estimate the generosity and candor of these words or the pleasure it affords the writer to meet Professor Thurston on common ground in the search for scientific truth.

The following analysis of a pair of indicator diagrams will illustrate a phase of the law of condensation of steam in which the ratio between the actual and the indicated steam seems to become a constant and a minimum for all points of cut-off.

The writer owes the diagrams to the thoughtful courtesy of Mr. J. Vaughan Merrick, of the Southwark Foundry, Philadelphia.



Porter-Allen Engine. Post-office Building, Philadelphia, March 30, 1881. Scale 40 pounds per inch.

Engine non-condensing.
Stroke $24'' = 2$ ft.
Clearance $4\frac{1}{2}$ per cent. of stroke $= 0{\cdot}09$ ft. deduced from expansion curve.
Diameter $14\frac{1}{2}'' = 1{\cdot}208$ ft.
Abs. initial pressure, back end, 87 lbs.
" " " front end, 89 lbs.
" " " mean, 88 lbs.
" back pressure at midstroke, 16 lbs.
Temperature of initial steam, 318·45 deg. Fahr.
Specific vol. of initial steam, 300·8.

Temperature exhaust steam, 216·29 deg. Fahr.
Number of strokes 400 per minute.
Mean eff. pressure, front end = 20·62
" " " back end = 17·24 } Amslers' Polar. Planimeter used.
" " " mean = 18·93
Indicated horse power = 74·91.
Max. back pressure = pressure at cut-off.
(e) Point of cut-off, front end } = 0·168 mean value.
" " back end }
(k) Clearance (true) 0·043.
Cut-off less compression ($e-k$) 0·125. = $\frac{1}{8}$.

Indicated steam $\frac{859375}{300\cdot8 \times 18\cdot93 \times 8} = 18\cdot86$ lbs. per horse-power per hour.

Since the back pressure reaches the initial pressure we can reasonably assume that the condensation of the piston and cylinder heads disappears entirely or is greatly reduced, therefore equation (8) JOURNAL FRANKLIN INSTITUTE, March 1884, assumes the following form:

$$r = 1 + \frac{S(T_b - T_e)}{62\frac{1}{2}N} C\frac{4}{d}.$$

If we let $A = \frac{62\frac{1}{2}}{S}$ and $D = \frac{T_b - T_e}{N} C$

we have

$$r = 1 + \frac{D}{A}\frac{4}{d}$$

In the present case $A = \cdot207$

In the present case $D = \cdot0025$ if we assume $C = \frac{1}{100}$ lb. from Harris-Corliss Engine. J. F. I., March, 1884.

$$r = 1 + \frac{\cdot0025 \times 4}{\cdot207 \times 1\cdot208} = 1\cdot04.$$

Therefore the actual water from boiler is $18\cdot86 \times 1\cdot04 = 19\cdot61$ lbs. per horse-power per hour. This of course makes no allowance for losses in pipes and by radiation, but only for the loss by the unavoidable internal cylinder condensation, assuming dry saturated steam to reach the cylinder.

The fraction of the stroke b, at which the exhaust port closes is ·236 from the nearest end.

Rendering fixed the condition that the exhaust steam shall always be compressed to the initial pressure, and seeking the cheapest point of cut-off, we have a modified form of eq. (16) (J. F. I., March 1884).

$$e = \frac{B\left[1 - b\left(1 - \text{nat. log.}\frac{b}{k}\right)\right]}{P_b} + k - k \text{ nat. log. } \frac{1}{e}$$

From the data we have

$$\frac{B\left[1 - b\left(1 - \text{nat. log.}\frac{b}{k}\right)\right]}{P_b} = 0{\cdot}212$$

$$k = 0{\cdot}043$$

Assume $e = \frac{1}{4}$ we have

$$0{\cdot}25 = {\cdot}212 + {\cdot}043 - {\cdot}059 = {\cdot}196.$$

Assume again $e = \frac{1}{5}$ we have with sufficient accuracy

$${\cdot}20 = {\cdot}212 + {\cdot}043 - {\cdot}069 = {\cdot}186.$$

About $\frac{1}{5}$ cut-off then proves the point of cheapest cut-off under existing circumstances.

This is the true cut-off and includes clearance.

Under existing circumstances the point of maximum economy is slightly overrun, but the engine will, in all probability, have an increased load put upon it and cut-off later in the stroke than 17 per cent of the volume. As installed greater economy cannot be reached by the engine, and the end of any possible economy by expansion is reached.

The perfection of the expansion and compression curves would seem to indicate tight valves and piston.

There was evidently an interval sufficient to permit a change of the regimen of the engine between the taking of the steam chest diagram and that from the back end of the cylinder.

I do not know that I have ever seen diagrams more completely fulfilling all the mechanical and economic conditions of a high speed non-condensing engine of small size.

It is of interest to observe from the formula that the condition placed that the compressed exhaust steam shall reach the initial pressure renders the ratio of the indicated to the actual steam a constant, for all points of cut-off.

The steam chest diagram by its sudden drop and rise shows this condition not to have been precisely fulfilled, but it is doubtful if the exact fulfillment of such a condition can be demanded of any engine in actual use for ordinary purposes.

Philadelphia, May 9, 1884.

TURBINES.

By DeVolson Wood.

The chief object of this communication is to pass a criticism upon Professor Rankine's treatment of turbines as given in his work on the Steam Engine and other Prime Movers, pp. 189–199. If my audience were before me with book in hand, it would require but a few words to explain the matter, but considering it to be scattered, and variously limited as to time for the study of the question, I will analyze it in detail.

On page 195 of the work referred to is the statement: "The above are general expressions for all turbines with guide blades;" which, being without qualifications, might be taken literally as applicable to turbines of all manner of construction and run at any speed. But in fact the author has so restricted the problem that it can apply only to the three classes—outward flow, inward flow and parallel flow—and further, that each of these classes must be constructed in a particular way, and run at a certain definite speed. Thus, he states, on page 191, "In treating of the efficiency of the turbine, it will be assumed that they are constructed of the forms and proportions, and worked in the manner most favorable to efficiency, according to rules which will presently be explained." These rules are few in number, and restrict the wheel to a special kind.

In attempting to treat of the three classes of turbines as one, Rankine is obliged to construct language so that it will be equally applicable to any one of them, and although much is gained in generality in the analysis by this process, yet something is sacrificed to definiteness of expression and idea. We prefer to confine the attention, at first, to one form only, and for this purpose choose the outward flow wheel, after which the notation may be so interpreted, if possible, as to apply to other forms. In Rankine's treatment, the energy of the water due to its descent while in the parallel flow wheel is neglected, which, in many cases, is too important to be neglected.

The rules given by Rankine for the outward flow turbine are: "The first element, *E*, of the vane *EL* of the wheel must be normal to the inner rim *EG*, and hence will be radial," page 190. "The wheel shall be so constructed that the radial velocity of the water through it shall be uniform;" "The wheel shall have such a speed as that

the tangential velocity of the water on entering the wheel shall equal the velocity of the inner rim of the wheel;" "The tangential velocity, or velocity of whirl *relatively to the wheel*, on leaving the wheel, shall be equal and contrary to that of the outer rim of the wheel; and the wheel passages must be constantly full," p. 193. Adopting the notation of the author, we have $r = OE =$ the radius of the inner rim of the wheel, $nr =$ the radius of the outer rim, where the water quits the wheel, $a =$ the angular velocity of the wheel, ar and $nar =$ the two rim velocities, $\alpha = FEA =$ the angle between the last element of the guide plate CE and the inner rim GE, $\beta = KLH =$ the angle between the last element of the vane EL and the outer rim HL. $V =$ the actual velocity with which the water enters the wheel, $v = V \cos. \alpha =$ the tangential component of the velocity, called by Rankine the velocity of whirl, and $w =$ the velocity of whirl *relatively to the vane*.

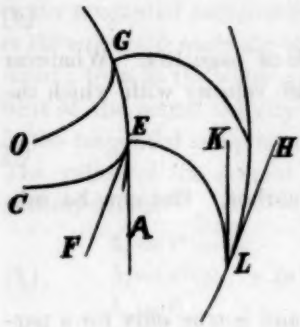


FIG. 1.

Then, since the velocity of whirl on first entering the wheel is to equal the velocity of the wheel at that point (top of page 193), we have

$$v = ar \qquad (a)$$

and since the water is to leave the wheel without whirl (bottom of page 192),

$$w = nv, \qquad (b)$$

and since the radial velocity is to be uniform (p. 192),

$$\tan. \alpha = n \tan. \beta; \qquad (c)$$

which equations are the same as those of the author.

It is a principle of mechanics that when the forces of a system consist only of the mutual actions and reactions between the parts of the system, the moment of the momentum will be constant during the motion. In the turbine acting without impulse, and friction being neglected, the motion is produced by pressure between the water and floats, and hence the above principle is applicable, and the moment of the momentum lost by the water will be imparted to the wheel. This is the principle used by Rankine, pages 193 and 194.

If $m = DQ \div g$, be the mass of water flowing through the wheel in a second, then will the moment of the momentum of the water on entering the wheel be

$$mvr \qquad (d)$$

which is the author's equation at the middle of page 194. Whatever be the velocity of the wheel, the tangential velocity with which the water quits it, will be

$$nar - w, \qquad (e)$$

which is the next expression given by the author. But now he substitutes nv for w (equation (b), making

$$nar - w = n(ar - v). \qquad (f)$$

But it is not *generally* true that $w = nv$, and is true only for a particular speed; and in this case the particular speed is given by equation (a) which will reduce (f) to zero. The author's equations (2) and (3), page 194, are, therefore, not *generally* true, and are true only for $v = ar$; and this value reduces the author's equation (3) to

$$Ma = mvra, \qquad (g)$$

where M is the moment of a couple. This result follows directly from our equation (d) by multiplying it by a, and may be reduced by means of equation (a) to

$$Ma = mv^2. \qquad (h)$$

It is worthy of note, in passing, that the dynamic effect in this case is *twice* that due to the kinetic energy of the water, and hence one-half must be due to direct pressure; and if the entire effect of the water were utilized by the wheel, the head due to the velocity of the water entering the wheel would be one-half the head in the supply chamber, but as there is inevitably a loss, the head due to that velocity will be less than one-half the total head, the exact value of which will soon be found.

Passing now to page 195, and following the *method* of the author, considering the total energy expended as divided into several heads; we have, h_1 the head due to the tangential component of the velocity as it leaves the guide plates; h_2 the head due to the radial component of the same velocity, called the velocity of flow, and these added will be the head due to the velocity with which the water issues from the gates; h_3 the head due to the tangential component of the velocity with which the water enters the vanes of the wheel *relatively to the*

wheel; then as the water is passing through the wheel we have h_4 the head due to the action of the wheel on the water, which, being an energy imparted by the wheel to the water, will be negative; h_5 the head due to the tangential component of velocity, or velocity of whirl *relatively to the vane* as it quits the wheel, called the reversed relative velocity of whirl; then as the water quits the wheel we have, h_6 the radial component of the actual velocity with which the water quits the wheel, and h_7 the tangential component of the same, or the final velocity of whirl. The values of the several heads, for the conditions prescribed by the author, will be

$$h_1 = v^2 \div 2g, \qquad h_5 = w^2 \div 2g,$$
$$h_2 = v^2 \tan.^2 a \div 2g, \qquad h_6 = n^2 v^2 \tan.^2 \beta \div 2g,$$
$$h_3 = 0, \qquad h_7 = 0,$$
$$h_4 = -(n^2 r^2 a - r^2 a) \div 2g = (1 - n^2) r^2 a^2 \div 2g.$$

But h_6 is not only the same as h_2 in value, but as the wheel is constructed and operated, one is simply the repetition of the other, and hence one of them must be suppressed, and in order to conform with the notation of the author h_2 will be canceled. Hence we have for the head in the supply chamber

$$h_0 = h_1 + h_3 + h_4 + h_5 + h_6 + h_7$$
$$= [(1 + n^2 + n^2 \tan.^2 \beta) v^2 + (1 - n^2) a^2 r^2] \div 2g, \qquad (i)$$

which is the author's equation (4), page 195, and thus far the analysis is correct. But we observe that this equation is true only for the wheel as made and when run with the velocity $v = ar$. Were it not so run as to make the final tangential velocity zero, h_7 would have a finite value, and if the wheel were not constructed for a uniform radial flow h_2 and h_6 would not be equal, and were it not constructed and run as described, we would not have $h_3 = 0$, nor $w = nv$. Now making $v = ar$, equation (i) becomes

$$h_0 = (2 + n^2 \tan.\beta) v^2 \div 2g, \qquad (j)$$

which is the author's equation (2), page 196.

We claim that Rankine errs in all his analysis where he considers ar as different in value from v; that on page 195 following equation (6) it should read: The above expressions are true for the three classes of turbines, when constructed as described, and run with the velocity $v = ar$ as stated; that all his equations on pages 195 to 200 are erroneous except within the above conditions; that the solution of reaction

wheels, Article 176, is far-fetched if not logically inaccurate, wherein he makes $nr = r_1$ after assuming $r = 0$, and, similarly, nz finite after assuming $z = 0$, although his final result is correct; that it is a mere fortunate coincidence that the results on page 199 "agree exactly with experiment." This last conclusion, by the author, is remarkable, in face of the fact that experimental results are always more or less discordant. The fact that the efficiency of a turbine is near the maximum for quite a range of velocities, doubtless aided in this remarkable verification of the formulæ.

The fact that equation (*i*) is not general, might be inferred from the results of an attempt to discuss it. Thus, h_0 being constant for any particular case, v must vary inversely as a, and would be a maximum for $a = 0$, in which case the wheel would be at rest; but it is known that the resulting value for v is not only erroneous, but that the general result is incorrect, for it is true that v increases with a up to a certain limit. Again, a would be a maximum for $v = 0$, a result strikingly absurd. It is hardly necessary to examine these conditions further, but we notice the fact that according to the author's equation 7 (page 195) for parallel flow turbines, the head due to the velocity of the water at entrance is independent of the velocity of the wheel, a result which would also be very absurd had he not previously established the condition that $v = ar$.

The following is all the analysis necessary for finding the efficiency of the turbine described by Rankine, when run with the velocity $v = ar$. The moment of the momentum of the water on entering the wheel will be

$$mvr$$

and this will be the entire moment of the momentum, imparted to the wheel since there will be no final velocity of whirl; and the work done by the wheel on this account, per second, will be

$$Ma = mvra = mv^2. \qquad (k)$$

The total energy due to the head in the supply chamber will be the energy imparted to the wheel *plus* the energy lost by the final velocity of flow. The value of the latter will be

$$\tfrac{1}{2}mn^2v^2 \tan.^2\beta; \qquad (l)$$

hence the total energy due to the head will be the sum of (*k*) and (*l*), or

$$Wh_o = \tfrac{1}{2}m(2 + n^2 \tan.^2 \beta)v^2$$

where W is the weight of the mass m; hence

$$h_o = (2 + n^2 \tan.^2 \beta)\frac{v^2}{2g},$$

and the maximum efficiency will be

$$\frac{Ma}{Wh_o} = \frac{2}{2 + n^2 \tan.^2 \beta}$$

It will be observed that in this brief solution no reference has been made to centrifugal force, and yet the same result has been obtained as by those who resolve the problem by other methods. In fact, in motors receiving their power from the energy of the fluid passing through them, the actual centrifugal force is self-neutralized; for it is energy imparted to the water by the wheel, and hence primarily at the expense of the energy of the outflowing jet; but when the water which has received this energy escapes it will impart to the wheel the energy which it has thus acquired. Or, to put it in another light, if it were possible for the outflowing water to impart this increased energy to the water in the wheel and at the same time prevent it from imparting its energy to the wheel, the wheel could not do as much work as it would if the centrifugal force were neutralized. Thus, if water flows from A to B along a radial arm in the same time that the arm rotates from AB to AC, the actual path of the water will be some curve, AFC, longer than AC, and hence the velocity imparted to the water will be greater than if its path had been AC in space; but if the water escapes in the direction CD, normal to AC, in the former case it will be deflected through the obtuse angle ECD, while in the latter it will be deflected through a right angle. Generally, the greater the angle of deflection of a jet (less than 180°), the greater the pressure exerted in the opposite direction; hence the stream whose actual path is AFC will exert a greater pressure on the arm at C in the direction DC, than if the path were AC in space; thus compensating for the energy expended in producing an increased energy. This view of the case may remove a difficulty sometimes met with in the compara-

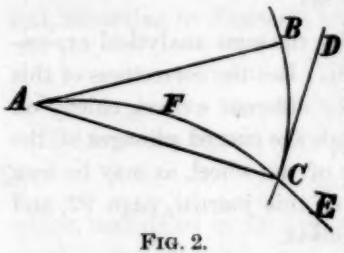


FIG. 2.

tive study of Barker's mill and the Whitelaw (and Scottish) turbine. In the former the water is carried around in the arms, while in the latter the water may be, comparatively, at rest in the body of the wheel in reference to the earth. The greater efficiency of the latter is due chiefly to the reduction of friction and of *whirls* in the wheel, and not to the difference in the actual centrifugal force of the water.

These motors may all be analyzed by means of the principles of energy, and without involving the idea of centrifugal force, and the true action of the water may, in some cases, be more clearly seen by this mode of treatment; while, on the other hand, every change of direction of a moving body may be considered as the result of a centripetal action on the body, the equal opposite of which is centrifugal. But either of these modes of disposing of the principle offers no explanation of its use as employed by the most eminent writers. On page 195 of Rankine's work, above referred to, is the expression, "to balance centrifugal force, the head

$$a^2 r^2 (1 - n^2) \div 2g,"$$

and Wiesbach and many other authors give the same analytical expression for the effect of the centrifugal action. But the correctness of this expression has been called in question by different writers, chiefly on the ground that the water flowing through the curved passages of the wheel does not have the angular velocity of the wheel, as may be seen by articles in the last August number of this journal, page 92, and also in the September and December numbers.

We, therefore, first of all examine its correctness. The principle to be considered may be stated thus:

A particle, mass m, in a tube has an initial velocity c_1 *along the axis of the tube, while the tube rotates with a uniform angular velocity; required the subsequent velocity of the particle.*

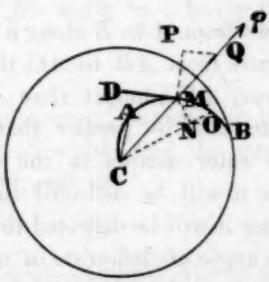


FIG. 3.

Let *CAMB* be the tube rotating about a vertical axis through *C*, and at any instant, *t*, let the particle be at *M*; *A* the initial position when the particle has an initial velocity, c_1, *relatively to the tube*, and *B* the terminal position where the velocity is c_2 also relatively to the tube. Also let

ω = the angular velocity of the tube about *C*,

$r_1 = CA$, $r_2 = CB$, $\rho = CM$, $s =$ any portion of the arc AMB, $ds = MO$, $d\rho = NO$, $v_1 =$ the circular velocity of the disc at $A = r_1\omega$, $v_2 =$ the circular velocity at $B = r_2\omega$.

To find the law of the force acting on the particle conceive, at first, that the particle is held at M so as to be at rest relatively to the tube while rotating with the tube; there will be an outward pull on the axis C due to the centrifugal force of the particle, the expression for which is

$$\varphi = m\omega^2\rho.$$

If the restraining force be withdrawn, that component of the centrifugal force parallel to the tangent of the tube at that point, will produce motion along the tube, while the component normal to the tube will simply produce a pressure against the side of the tube. Let $MQ = \varphi$, draw MP perpendicular to the tangent DM, and QP parallel to it, MN perpendicular to the radius vector CO, and let $QMP = \theta = NMO$, then

$$PQ = \varphi \text{ sin. } \theta,$$

and, according to Newton's second law, we have

$$m\frac{d^2s}{dt^2} = m\omega^2\rho \text{ sin. } \theta. \qquad (m)$$

But from the figure, *ultimately*,

$$ds \text{ sin. } \theta = d\rho,$$

which, multiplied by the preceding equation, member by member, and equal factors canceled, gives

$$\frac{ds}{dt^2}\frac{d^2s}{dt^2} = \omega^2\rho\, d\rho,$$

and integrating,

$$\frac{ds^2}{dt^2}\Big]_{c_1}^{c_2} = \omega^2\rho^2\Big]_{r_1}^{r_2} \qquad (n)$$

or
$$c_2^2 - c_1^2 = \omega^2(r_2^2 - r_1^2) = v_2^2 - v_1^2; \qquad (o)$$

also,
$$\tfrac{1}{2}m\,c_2^2 - \tfrac{1}{2}m\,c_1^2 = \tfrac{1}{2}m(v_2^2 - v_1^2). \qquad (p)$$

The left member of the last equation is the energy gained or lost, *relatively to the tube*, there being a gain in moving away from the centre, and a loss when moving towards it. Hence

The energy gained or lost, RELATIVELY TO THE TUBE, *by a particle moving in a tube rotating uniformly about a vertical axis,* the change of velocity of the particle being due solely *to the pressure of the walls of*

the tube against the particle, equals one-half the mass of the particle into the difference of the squares of the circular velocities of the tube at the initial and terminal points of the path of the particle. Also,

The RELATIVE ENERGY *gained or lost is independent of the form of the path,* and dependent only upon the radii vectores of the initial and terminal points, and the angular velocity of the tube. Hence, also,

The ACTUAL ENERGY, *or energy in reference to some object considered fixed, as the earth, will depend not only upon the* VELOCITY RELATIVELY TO THE TUBE, *but also upon the direction of the tube in reference to the radius vector at that point,* and *the actual velocity of the tube at that point.*

The first of these inferences is similar to that of the energy gained by a body descending under the action of gravity from one level to another along a fixed path, where the change of energy is dependent only upon the difference of heights.

The second inference is only another wording of the former, in which the energy gained is independent of the path.

The third inference is similar to that of a body descending along a path in motion, where the actual energy is dependent upon both the relative velocity along the path and of the path itself.

The equation of the path of the particle in space will depend upon the equation of the tube relatively to the rotating disc, as well as upon the motion along the tube. If the particle be at M and in an element of time, dt, it moves along the path to O, the result will be the same as if it moved from M to N in a circular arc, and thence to O along the radius vector CO. The tube having a rotary motion, assume that the point M is carried forward in a circular arc to A in an element of time, a distance $= \rho\omega dt$, where $\rho = CM$; then will the final position be the same as if it moved from M to A, thence from A to B, the distance $AB = MN$, thence from B to D along the radius vector CD, a distance $BD = NO$. Let $f(\rho,\beta) = 0$, be the equation of the curve MO relatively to the rotating disc; $F(r,\varphi) = 0$, the equation of the path MD relatively to the earth; then will $MCO = d\beta$, $DCM = d\varphi$, $rd\varphi = MB$, $MN = \rho d\beta$; and

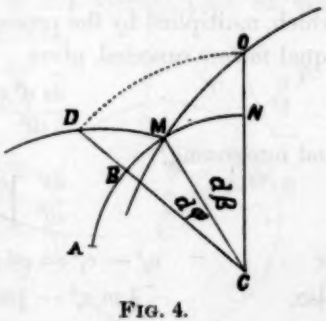


FIG. 4.

$$rd\varphi = \rho\omega dt - \rho d\beta, \tag{1}$$

$$r = \rho, \text{ since } CO = CD, \tag{2}$$

$$\therefore dr = d\rho, \tag{3}$$

from theory of curves, $$ds^2 = \rho^2 d\beta^2 + d\rho^2, \tag{4}$$

from eq. (*n*), $$ds^2 = \omega^2 (\rho^2 - r_1^2 + c_r^2)\, dt^2, \tag{5}$$

where r_1 and $\omega^2 c_r^2$ are the constants of integration corresponding to r_1 and c_1 in equation (*o*). These equations combined with the equation of the curve of the tube, $f(\rho,\beta) = 0$, will, by elimination, give

$$\varphi = \int \psi(r)\, dr,$$

which integrated will give the required locus. If the tube be radial, we have $\beta = 0$, and equations (4) and (3) give

$$ds = d\rho = dr,$$

which combined with equation (5) gives

$$\omega t = \int \frac{dr}{\sqrt{r^2 - r_1^2 + c_r^2}}$$

$$= \log. \left[\frac{r + \sqrt{r^2 - r_1^2 + c_r^2}}{r_1 + c_r} \right],$$

since $t = 0$ for $r = r_1$. Transforming,

$$r = \tfrac{1}{2} r_1 (e^{\omega t} + e^{-\omega t}) + \tfrac{1}{2} c_r (e^{\omega t} - e^{-\omega t}),$$

which is the required equation. If r_1 and c_r are both zero, r will be zero for all values of t.

The exact path, however, is of little importance compared with the relative directions of entering and quitting the wheel.

The change in the actual energy of the particle depends upon the initial and terminal actual velocities. Thus if w_1 be the initial *actual* velocity and w_2 the terminal *actual* velocity, then will the change in *actual* energy be

$$\tfrac{1}{2} m (w_2^2 - w_1^2). \tag{q}$$

It appears from equation (*o*) that the angular velocity of the particle is not involved in the change of *relative* energy; hence, this effect will be the same whether the path be straight and radial from r_1 to r_2, or straight and inclined between those points, or a spiral passing several times around the centre between circumferences whose radii are

r_1 and r_2; or finally, if it passes without and within those circumferences having only their initial and terminal points at distances r_1 and r_2 from the axis.

Therefore, Mr. Frizell, in the last August number of this JOURNAL, page 94, erred when he said "ω represents the angular velocity of the body M," for it represents the angular velocity of the disc or tube; but is correct in saying "This movement is partly angular and partly radial. The angular element of this motion must be added to or subtracted from the angular motion of the disc to find the true angular velocity of the body M on which the centrifugal force depends." But he errs in assuming, as the close of the last extract seems to imply, that "the centrifugal force" is sought; when, in fact, it is the *energy* gained or lost *relatively to the tube* due to the action of the tube on the body, and not even the *actual* energy.

The distinction between force, relative energy, and actual energy, should be kept in mind. He also errs, if we understand him correctly, in assuming (p. 95) that "the above expressions would be true if the body M had merely a radial movement on the revolving disc," for here, as in other cases, equation (o) applies only to the motion along and relatively to the path, and hence, in this case, to the radial velocity. Thus, to illustrate, take a more simple case, that of a particle starting at the axis with no finite initial velocity and moving along a radial arm, then equation (o) gives

$$c_2 = v_2.$$

which is the *radial* velocity with which the body will quit the tube; but since it also has the circular velocity v_2 the *actual* velocity with which it quits the arm, will be

$$\sqrt{v_2^2 + v_2^2} = v_2\sqrt{2}.$$

Referring now to the works quoted by Mr. Frizell, "Weisbach, 'Hydraulics and Hydraulic Motors,' by Prof. Dubois, introduction, page xliii" (quoted also, J. F. I., p. 94), the author errs where he states, "If, then, a body moves in a rigid path or groove, which revolves about a fixed axis, the *vis viva* of the body is increased or diminished by the product of the mass and the difference of the squares of the velocities (v_2^2 and v_1^2)," etc.; unless it be understood that the *vis viva* referred to is that *relatively to the tube*. The relative energy may be increasing while the actual energy is decreasing.

The same author errs, page xliv, where he states, "The work which the body is capable of performing before coming to rest is

$$W = \frac{c_2^2 - c_1^2}{2g} G = \frac{V_2^2 - V_1^2}{2g} G;" \qquad (r)$$

for this is neither the actual nor the relative energy of the body; but simply the relative energy gained or lost, the destruction of which would simply restore the relative initial energy. The expression bears no known relation to the actual energy; and, hence, the text appears to establish the correct equation upon an erroneous basis.

In the "Mechanics of Engineering," Coxe's translation, the author appears to err, page 611, where he states, "We have the centrifugal force of the body

$$P = \omega^2 Mz,"$$

unless the author means that ω is the angular velocity of the particle, which is nowhere stated, but, on the contrary, it is stated in the notation of that author that "ω is the angular velocity of the top," meaning *tube*, as we are using it.

The expression, however, may be so explained as to be consistent. The object of the analysis is to find the velocity relatively to the disc. According to the principle of D'Alembert the force which accelerates a body's motion is exactly equal but opposite to that which would maintain equilibrium, and is such that if the body be at rest, the equal opposite force would prevent motion. A particle will be at rest relatively to a uniformly rotating disc if it have the same circular velocity as the disc and about the same axis, and is also acted upon by a constant force directed towards the centre of motion just sufficient to keep it in a circular arc. The uniform angular velocity will be maintained with no expenditure of force, and the latter condition may be secured by a string attached to the body and the axis of rotation, the tension of which will equal the centrifugal force of the body, $M\omega^2 z$. This is the centripetal force of the string upon the body, and equals the centrifugal force of the body upon the axis of rotation. If, now, motion is to be along a fixed tube on the disc, resolve the centripetal force (assuming that the motion is to be away from the centre) normally and tangentially to the path; these components, substituted for the string, will also keep the particle at rest *relatively to the tube*. The normal component, though it exists after the string is severed, can produce no motion *relatively to the tube;* but the tangential component,

after the string is severed, will produce motion along the tube, the circumstances of which may be determined by Newton's second law. Weisbach, however, determines the velocity according to the principles of energy. Thus, if $M\omega^2 z$ be the force in the direction of the radius z, the energy produced by working from radius r_1 to r_2 will be

$$M\omega^2 \int_{r_1}^{r_2} z\,dz = \frac{1}{2} M\omega^2 (r_2^2 - r_1^2) = \frac{1}{2} M(v_2^2 - v_1^2).$$

That author also errs, page 612, where he states that "The energy stored by the body in describing the path *AMB*, supposing no other force to act upon the body will be," our equation (*r*); unless it is understood to mean *energy relative to the tube.* This is the more worthy of note, because the language is substantially the same as that given at the bottom of the same page, although the latter necessarily refers to *actual energy.*

These views and references are all in accordance with those given, possibly first, by M. Poncelet in his historic solution of the Fourneyron turbine (*Comptes Rendus*, 1838, p. 269), where he says "The equation of the relative movement in the interior of the wheel, having regard to the action of the centrifugal force which develops, per second, a quantity of work

$$\tfrac{1}{2} M (v_1^2 - v^2);"$$

where v_1 is the velocity of the inner rim and v that of the outer rim; which expression is the same in value as that given by Rankine. It is well to note that this author correctly refers to the *relative* movement, and to the work done, and not merely to "balance *centrifugal force*" as Rankine, though with questionable accuracy, has stated. Rankine's expression is, at best, merely suggestive of the source of the analysis, but not descriptive of it.

If a single particle passed through a tube free to rotate, doing no external work, the angular velocity of the tube might, and generally would, constantly vary; for while the energy of the particle was being imparted to the tube, the velocity of the latter would increase, and *vice versâ.* If there be a continuous flow of particles, work may be done at a constant rate, and thus the condition of those turbines in which the water enters and flows as a free jet, be realized. In turbines of the Fourneyron type there is usually a pressure, either positive or negative, at the inner rim of the wheel.

In the wheel discussed by Rankine the effect of reversing the direc-

tion of flow of water relatively to the vane may be found by considering the initial circular velocity as v and the terminal as zero, then will the entire energy lost to the water and imparted to the wheel from this cause be

$$\tfrac{1}{2}mv^2 - \tfrac{1}{2}m.0^2 = \tfrac{1}{2}ma^2r^2,$$

which is at once the sum of the heads due to the centrifugal action and reversed relative velocity of flow, as given by our author, page 195, when $v = ar$ as it should in his analysis; and this added to the kinetic energy of the water flowing into the wheel, which is $\tfrac{1}{2}mv^2$, gives mv^2, as before.

Or, in accordance with a better philosophy, this wheel, run at this speed, may be analyzed by considering that the radial flow passes directly through the wheel and its energy lost, while the tangential velocity (or velocity of whirl) is gradually and fully destroyed in the wheel; its entire energy having been imparted to the wheel, and hence the case is similar to that of a jet flowing tangentially into a hemispherical vane moving in the same direction as the jet with one-half its velocity; in which case the pressure against the vane in the direction of motion is known to be mv; hence in the wheel the work per second will be

$$mv.ra = mv^2$$

as before.

It is interesting to trace the velocities of the water in the wheel. The initial velocity along the vane will be

$$v \text{ tan. } a,$$

and the terminal velocity

$$nv \text{ sec. } \beta;$$

hence, by the aid of equation (c), we have

$$\frac{nv \text{ sec. } \beta}{v \text{ tan. } a} = \text{cosec. } \beta;$$

hence the velocity *relatively to the vane* at exit will be cosec. β times that at entrance; and, practically, may be, say, 3, 4, or 5 times that velocity; but *relatively to the earth* it will, at entrance, be comparatively greater and quit with a much smaller one.

This, however, is not the case with all turbines; for if the water enters the wheel as a free jet it will pass along the vane with a uniform velocity *relatively to the vane*, and hence the radial velocity, or velocity

of flow, will be variable, being greatest where the tangent to the curve of the vane coincides with the radius of the wheel at that point, and diminishing beyond. In this case the cross section of the stream must be uniform, and the velocity with which the water issues from the gates will be that due the total head. The velocity of the wheel and the conditions for maximum efficiency for this case may easily be shown graphically. Thus, let *FE*, tangent to the guide plate *CE*, represent the velocity with which the water issues into the wheel at *E*. Let *AE* represent the velocity of the inner rim of the wheel, and joining *A* and *F*, *FA* will represent the velocity in magnitude and direction of the water *relatively to the float EGH*, and hence the first element of the float, or that at *E* should have the direction of *FA* when correctly found. The water will pass around the curve *EGH* with a uniform velocity of *FA relatively to the float*, the passages having a uniform cross section, and quit the wheel with the relative velocity $HI = FA$. The velocity of the outer rim will be

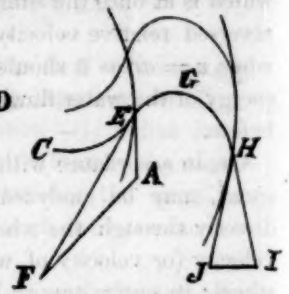


FIG. 5.

$$JH = n.AE,$$

where n is the ratio of the second radius to that of the first; and hence *JI* will be the actual velocity with which the water quits the wheel. If *JI*, as thus found, be parallel to the radius of the wheel *DH*, passing through H, the best conditions will have been secured; but otherwise, assume a new value for *AE* and repeat the operation until *JI* has the required direction; then will the resulting direction of *FA* be the proper direction of the first element of the float *EG*, and *AE* the velocity of the inner rim of the wheel for best effect, and *JI* the velocity lost. The efficiency will be

$$\frac{FE^2 - JI^2}{FE^2}$$

But this analysis is applicable only when the *relative* velocity along the vane is uniform. To secure this velocity and at the same time have the wheel passages full, the depth must vary from *E* to *H* inversely as the normal width between the consecutive vanes, making the developed vertical section of a vane similar to Fig. 6; which form is similar to

Boyden's diffusor, though the functions of the two are quite different. This illustrates why Rankine restricted his analysis to the case of full wheel-passages; for otherwise the action would have been that of a free jet instead of a stream so confined as to have a uniform radial velocity.

That the direction of flow of the water at exit should be radial for best effect, regardless of the construction of the wheel, may easily be shown. According to equation (q) w^2 should be as small as possible.

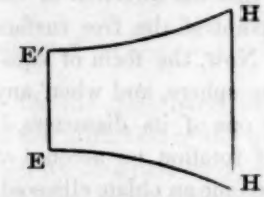


FIG. 6.

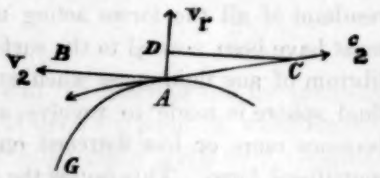


FIG. 7.

Let $AC = c_2 =$ the velocity of exit relatively to the vane AG, $AB = v_2$, the velocity of the wheel relatively to the earth. Take $AC = c_2$, and CD, parallel to $AB = v_2$ and join A and D; then will AD in magnitude and direction represent the actual velocity of discharge $= w_2$; and

$$w_2^2 = c_2^2 + v_2^2 + c_2 v_2 \cos. CAB.$$

Considering CAB and c_2 or v_2 as constant, we find w_2 a minimum for $v_2 = c_2 \cos. C$; which makes AD perpendicular to CD or to AB; one of the conditions assigned by Rankine. If now CAB be the variable, w_2 will be zero for $CAB = 180°$, in which case c_2 will be equal and opposite to v_2.

March 20, 1884.

Polynesian Hieroglyphs.—Abbé J. Bund has published a lithographic reproduction of a photograph, which was made, under the direction of the Archbishop of Tahiti, from a hieroglyphic tablet. The original was given to Father Zumbohm, on Easter Island, or, as the natives call it, Rapanui. The characters are engraved on a piece of wood, about 35 centimetres long and 30 wide (13·78 × 11·81 inches), by means of sharp stones. Some of them present resemblances to fishes, birds, men, and animals, while others seem to be merely fanciful. The repetition of similar characters, and the orderly arrangement, are such as to indicate an alphabetic meaning.—*Les Mondes*, March 15, 1884. C.

THE ELLIPTICITY OF PLANETS.

By L. D'AURIA.

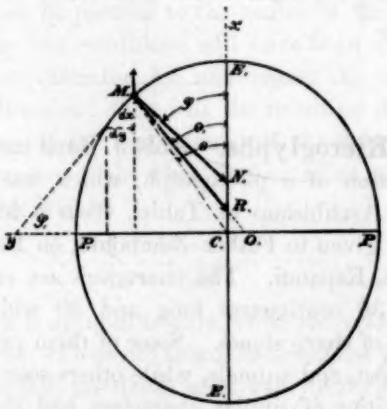
Admitting that planets were originally in a fluid state, however heterogeneous their respective masses may be considered, their form of equilibrium when fluid, must have been such that the direction of the resultant of all the forces acting upon any point of the free surface must have been normal to the surface itself. Now, the form of equilibrium of any fluid mass when at rest is the sphere, and when any fluid sphere is made to revolve around any one of its diameters, it becomes more or less flattened on its axis of rotation on account of centrifugal force. This causes the sphere to become an oblate ellipsoid, whose minor diameter coincides with the axis of rotation itself; and, therefore, the equation of any meridian line on the surface of any fluid mass revolving around an axis of inertia can be expressed by

$$a^2y^2 + b^2x^2 = a^2b^2.$$

Differentiating this equation we have

$$\frac{dy}{dx} = -\frac{xb^2}{ya^2};$$

and observing that the first member represents the cotangent of the



latitude φ of a point M, whose co-ordinates are x and y (Fig. 1), and

that $\frac{x}{y}$ represents the cotangent of the latitude θ of the same point referred to the centre of the ellipsoid; we have

$$\frac{\sqrt{1-\sin.^2\varphi}}{\sin.\varphi} = -\frac{b^2}{a^2}\frac{\cos.\theta}{\sin.\theta};$$

and

$$\sin.\varphi = \frac{\sin.\theta}{\sqrt{1-\cos.^2\theta e^2(2-e^2)}},$$

where $e^2 = \frac{a^2-b^2}{a^2}$.

On the other hand, let MR represent the direction and the intensity of the attraction of the whole ellipsoid upon the point M, which attraction we designate by g; and put $M0 = \rho$; angle $MRE = \theta_1$; angular velocity $= \omega$. Then, the resultant of the attraction g, and the centrifugal force at M, must coincide with the normal MN, for centrifugal force is parallel to EE; and since this latter force is expressed by $\omega^2\rho\cos.\theta_1$, we have for the resultant itself,

$$f = g\sqrt{1-\cos.^2\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right)};$$

and, therefore,

$$\sin.\varphi : \sin.\theta_1 = g : g\sqrt{1-\cos.^2\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right)};$$

$$\sin.\varphi = \frac{\sin.\theta_1}{\sqrt{1-\cos.^2\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right)}}.$$

Comparing this value of sin. φ with the preceding one, we find

$$e^2(2-e^2) = \text{tg.}\,\theta\,\text{cotg.}\,\theta_1\frac{\omega^2\rho}{g}\left(2-\frac{\omega^2\rho}{g}\right) + \frac{\sin.^2\theta_1-\sin.^2\theta}{\sin.^2\theta_1\cos.^2\theta}.$$

When θ and θ_1 become equal to each other, that is, when the point M is considered very near to the equator of the ellipsoid, then

$$\frac{\sin.^2\theta_1-\sin.^2\theta}{\sin.^2\theta_1\cos.^2\theta} = o;\ \text{tg.}\,\theta\,\text{cotg.}\,\theta_1 = 1;\ \rho = a;$$

and

$$e^2(2-e^2) = \frac{\omega^2 a}{g}\left(2-\frac{\omega^2 a}{g}\right);$$

$$e^2 = \frac{\omega^2 a}{g}.$$

Since the ellipticity is expressed by $\varepsilon = \frac{a-b}{a}$; we have

$$2\varepsilon - \varepsilon^2 = \frac{\omega^2 a}{g}; \quad [a]$$

and neglecting ε^2, we have, approximately,

$$\varepsilon = \frac{\omega^2 a}{2g}.$$

Now in the case of our planet,

$$\omega = \frac{2\pi}{86184}; \quad a = 6377278 \text{ meters}; \quad g = 9 \text{ meters } 81462;$$

(including centrifugal force). Hence,

$$\varepsilon = \frac{1}{578}.$$

This value is entirely too small compared with $\frac{1}{300}$ as deduced from geodetical measurement of arcs of meridians and parallels; but the discrepancy cannot be ascribed to incorrectness of equation $[a]$, since the latter has been deduced from a well established mathematical principle. It may be due partly to the fact that since the time the earth became compact enough to retain its form, its volume has been considerably contracted uniformly all around, which evidently increases its ellipticity; and partly to a retardation of the earth's axial rotation since that time, which also increases the value of ε, by increasing ω, in equation $[a]$. Both these causes, however, are based upon the assumption that our planet must have lost its fluidity long ago, although in its interior it may be yet intensely hot; and since there is no other way to account for the discrepancy in question, we must recognize in this an excellent confirmation of the opinion lately advanced by Sir William Thomson on the constitution of the earth as regards the observed phenomena of precession, nutation, and tides.

That the earth's axial rotation is subject to a certain retardation, has been almost evidently shown by astronomers in order to account for the apparent acceleration in the moon's orbital motion; and such retardation has been estimated at about ten seconds in a century.

The ellipticity of the planet Jupiter, computed approximately after the formula

$$\varepsilon = \frac{\omega^2 a}{2g},$$

is found to be $\frac{1}{24}$, while, according to observations, it should be about

$\frac{1}{17}$. The discrepancy here, which is due to the same causes above explained, is much less than in the case of the earth, and this seems to show that if at present the planet Jupiter is not perfectly fluid throughout, it is yielding enough to obey in a certain measure the forces which tend to decrease its ellipticity, a conclusion which is in perfect accordance with the observed physical conditions of this planet, and otherwise gives strength to our assumptions.

TO CHICAGO IN EIGHTEEN HOURS.

By Robert Grimshaw, M. E.

[Read at the Stated Meeting of the Franklin Institute, April, 1884.]

I have the honor this evening to submit to the Franklin Institute the outlines of a bold, but feasible project for making the regular run between New York or Philadelphia and Chicago, in eighteen hours, with comfort, safety, and cheapness. At present, the transit occupies from 27 to 37 hours, according to the route and the character of the train.

To accomplish the desired result, necessitates changes in engine, train, method, and permanent way.

Naturally, the limits of this paper do not permit me to rehearse all the details of the proposed selections and innovations; but the most important of them will be outlined, as a basis for discussion.

This paper is the outcome of a discussion started by me in the *American Journal of Railway Appliances* in December last; I have no patents to advertise and no axes to grind. Many of the suggestions in this paper are mine, others have been contributed by eminent mechanics, practically familiar with the building, repairing and running of high speed locomotives. I do not, however, propose to designate which are mine and which are not, having been much amused by hearing ideas, contributed or indorsed by leading builders and master mechanics, and some of which have been for some time in successful operation, characterized as impracticable and visionary. All I will say in this connection is, that whatever any of my hearers may consider as good and practical, no matter what it is, I do not claim. For anything which any one may consider particularly good for nothing, or old, or wild, or unfeasible, or idiotic, I accept full responsibility. I am perfectly aware that this

will result in my at once fathering and disclaiming all those ideas about which among my hearers there may be diametrically opposed opinions; but the inconsistency will be not mine, but that of the audience.

For such work, the engine needs, in a high degree, steaming capacity and economy of fuel, cylinder power and economy of steam, tractive power, adaptability of wheel base to the curves necessarily encountered, proper equalization and distribution of weight, prompt and safe control by throttle, reverse lever, and brake, exemption from tendency to leave the rails, particularly on curves and at switches; freedom from jerking, swaying, "wee-wahing," and hammering, and good behavior as regards spark throwing and heating of wearing surfaces.

This is, perhaps, asking a good deal in an engine; but the higher the standard and requirement, the better the attainment; and in all the points named, existing engines can be bettered.

Steaming capacity and economy call for good fuel and water, and proper draft, large grate and heating surfaces properly disposed, the grate kept properly covered and fire clean, water heated and purified before feeding; heating surfaces kept free from scale and sludge on one side, and soot and ashes on the other.

Cylinder power and economy demand high initial and mean effective pressures and low terminal and back pressures. This must be got by large port area without excessive passage clearance, and a better valve motion than the present shifting-link abortion, with its attendant throttling, wire drawing, exhaust choking, and lop-sided distribution.

To get high tractive power, the drivers must have as much weight upon them as the rails, joints and bridges will stand. There is no use in an engine being more than able to slip her drivers on up grades and with maximum train load, on icy rails.

We must distribute our reforms among the framing, running gear proper, fire box and appurtenances, boiler proper, stack, valves and steam passages, and valve-gear.

Perhaps, the necessity for simultaneous reform in so many elements may result in a hybrid type of engine; but it must be remembered that many hybrids are useful; one of them, the much maligned mule, is an indispensable factor in civilization.

For framing, I should select the bar type as perhaps the best underderstood by American builders, and best adapted to the permanent

way of the next decade. But it requires marked reform from the usual manner of making up. It needs to be stiffer vertically, to be better braced diagonally in a vertical plane, and freer from short, sudden changes in direction, and from welding flaws. It should be of mild steel, die-forged by pressure, as by hydraulic or steam toggle-presses, instead of anvil-forged by hammer blows. The angles should be well reinforced; and the whole frame considered as a truss subjected in its various parts to certain constant and known weight stresses, plus other intermittent racking, twisting and pounding strains. I trust that master mechanics and locomotive builders will pardon me for saying that the services of a good bridge engineer could be employed with

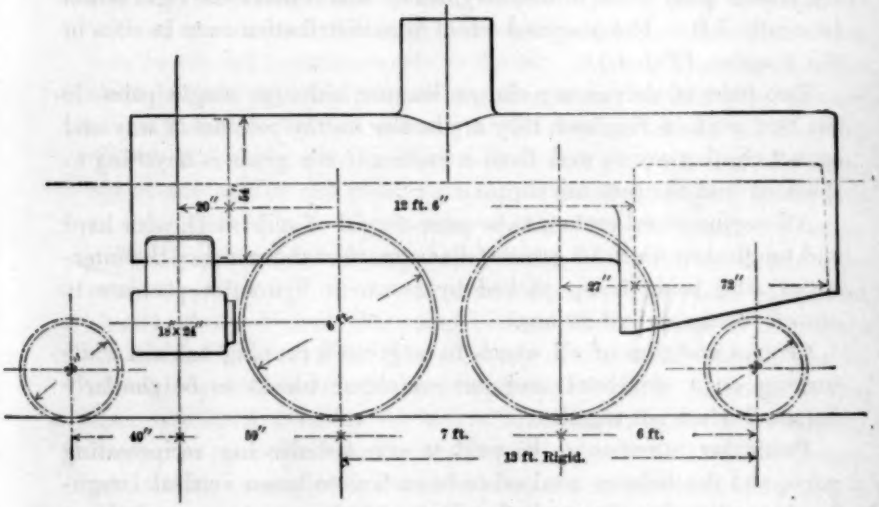


FIG. 1.—PROPOSED WHEEL DISTRIBUTION.

advantage in re-designing the framing of high speed American passenger engines.

I would propose for each horizontal member of the bar-frame, a beam rolled of ⊥ section, with considerable depth of web; jaws of same section, but with considerable re-inforce welded in the framing angles.

For wheel distribution, I propose two pairs of drivers, a "pony" or single pair leading truck, and a pony trailing truck.

Objection has been made that pony leaders are dangerous, and that a four-wheeled truck is necessary for safety. In reply to this, English fast engines have even rigid leaders, and often lead with the

drivers. I know of no instance where a locomotive has been derailed, owing to the pony truck, where the pony truck has been equalized with the front driving wheels.

A four-wheeled leading truck would increase the length of boiler and flues, and the dead weight of boiler and running gear, and not increase the traction.

Proposed diameter of drivers is 72″, placed 84″ between centres; of leading truck wheels 36″, 99″ in advance of leading driver centres; of trailing truck wheels 36″, 72″ back of rear driver centres.

The trailing truck may be rigid, giving 13 ft. rigid wheel base and total wheel base of 21¼ ft. Or the trailing wheels may be on a swinging bolster pony truck if necessary, which would make the rigid wheel base only 7 ft. The proposed wheel base distribution may be seen in the diagram, (Fig. 1.)

Two pairs of drivers are chosen because, although single pairs do the best work in England, they are harder on the permanent way and cannot climb away so well from a station if the grade is anything to speak of and the rails are slippery.

All engine wheel centres to be press-forged of mild steel, with hard and tough steel tires 1″ greater diameter than the centres; the interstitial ring being hemp packed by steam or hydraulic pressure to absorb shocks and vibrations.

Centres and tires of all wheels to be given a running balance while turning on a cock-head, and the completed wheels to be similarly balanced when put together.

Particular attention to be paid to counterbalancing reciprocating parts, and the balance attained to be such as to lessen vertical irregularities rather than fore and aft pulls.

The flanges of all wheels in the train are to be of extra depth and thickness, and those of the front drivers to be lubricated by grease-blocks as on Austrian railways, to lessen flange friction and wear of rails and flanges.

Rear drivers to be either flangeless, or with extra play in the wheels, in case the trailing pony does not have a swing motion.

Axles to be of mild steel with 10½″ x 8″ journals in phosphor bronze or equivalent bearings. Journals to be formed by pressing a ground hard steel sleeve over a mild steel center and then forcing on the wheel.

Power brakes to be applied on both sides of each driver, so as to

give increased friction and prevent strain and wear on axle-boxes, and on brasses of main and side rods.

As regards the brake, I make the following quotation from the *American Journal of Railway Appliances:*

"An important requisite is suitable and adequate *brake power.* This is of the first importance for safety, convenience and expedition. *First*—As already intimated, the power brake for such a train must be easily graded. For slow-ups, through centres of population, around curves and down grades, a brake is needed which will not go off like a cannon—using all its power when but part is required—but one which may be applied to just the extent which the engineer may desire, and no more. And this grading in brake power must be attainable without any mechanical change in the equipment other than that which may be effected instantaneously in the cab. *Second.* The needed brake must indicate accurately to the engineer, at any moment, the amount of brake power he has, not only on his engine, but also on his train. *Third.* It must be a brake which will at once give notice of any damage to any part of the train, without, necessarily, bringing it to a halt in a dangerous place. Or, in other words, the brake must apply automatically in case of damage, to remain set, or be instantaneously released, at the will of the engineer. *Fourth.* The brake equipment should be so devised that even a considerable damage to it will not disable the brake. *Fifth.* The efficiency of the brake should not be affected by sudden changes in temperature. *Sixth.* It should be free from liability to trouble from lack of equalization in the power applied to separate cars. *Seventh.* The brake power should be adequate, instantaneous in its application and release, and available at all times, in whole or in part. *Eighth.* It should be cheap, and as cheaply maintained as is consistent with the highest degree of efficiency and safety. *Ninth.* Above all, it should be free from any liability to creep on and *stall trains.*"

Springs to be in two parts, separated vertically by an open space and a central distance piece, so as to give by this open trussing greater strength for a given weight of metal.

In the matter of fuel, there are four classes to choose from: (1) lump coal, (2) "briquettes," or blocks of artificial fuel made from screened anthracite or bituminous slack, mixed in suitable proportions, and compressed by hydraulic machinery; (3) water gas, made in fixed plants at terminal and other stations, and compressed to fifteen or

twenty atmospheres in cylindrical mild steel tender tanks, or reservoirs; and (4) petroleum, vaporized or sprayed at the moment of burning, and at the varying rates required for the constantly varying work to be performed.

The artificial fuel of briquettes has the advantage of cheapness and compactness and of regularity in firing. Either compressed water-gas, or petroleum would give lightness of tender, and regularity and rapid and absolute controllability of evaporation, together with great capacity and high duty.

For the present we shall consider the engine to be designed for lump coal, or for "briquettes" of compressed coal slack.

Boiler to be of $\frac{7}{16}''$ mild steel, 56″ outside diameter, straight top made with only one longitudinal seam, and that on top; holes either drilled, or punched scant and reamed to size; hydraulic riveted and concave caulked; manhole to come in the dome and be reinforced with a mild steel ring.

I would prefer to do without the longitudinal seam by having the rings rolled seamless, or to do away with the girth seams by making the entire shell of one sheet, but at present neither of these plans can be carried out.

Distance from centre of front sheet to centre of stacks 20″. Crown sheet 27″ back of rear driver centres.

Thickness of dome $\frac{3}{8}''$; of extended smoke box $\frac{5}{16}''$, of smoke box $\frac{1}{2}''$. Height from top of rail to centre of boiler 7′ 3″.

235 basic steel tubes, each 12′ 6″ long between tube sheets, and 2″ outside diameter.

Objection might be made to the great length of tube, but they are only a foot or so longer than usual, and need give no trouble as regards tightness. This gives an external heating surface of tubes of 1,537 square feet, and a fire area through tubes, less ferrules, of 3·92 sq. ft.

Fire box 120″ long and 52″ wide, inside. Height of crown sheet above top of grate, at centre, 52″. Material of inside fire box copper, $\frac{1}{2}''$ thick at sides and front, $\frac{7}{8}''$ at back and $\frac{1}{2}''$ in crown.

Radial stays, forked at the crown sheet end.

Heating surface of fire box, 84 sq. ft., making a total heating surface of 1621 square feet.

Exhaust nozzle, if discharging into stack, 3″ x $3\frac{1}{2}''$ instead of $2\frac{1}{2}''$ x $3\frac{1}{2}''$, as is usual for 18″ x 24″ cylinders.

Duplicate sets of try cocks and glass water column, and regularly renewable fusible plugs, kept free from scale.

The fire box may be corrugated to give increased strength and surface, and permit of expansion and contraction without causing leaks.

If coal or briquettes are used, there will be a spring fire door, operated by the stoker's foot; a deflecting plate inside the fire door; a perforated bridge-wall; and arrangements for admitting either steam or heated air at will through the bridge-wall, or in the side walls, or in the closed ash-pan, which latter will have an air-tight "slat dump." The grate bars would be mostly water tubes, and there would be rocking sections for cleaning. There would be a live steam-blower in the stack.

Smoke box to be of the "extended" class, with spark arrester.

Experiments with the extended smoke-box on the Eastern Railroad show that "the engine will make steam with her exhaust tips from $\frac{1}{8}$ to $\frac{1}{4}$ inch larger in diameter, with the extension" than without; that it gives 15 per cent. minimum fuel saving; lessens smoke, and "throws whatever sparks do come through so high that they are extinguished before reaching the ground."

The fire-box to be supplied with two-part doors, operated by a treadle. There should be a brick arch on insulating water-tubes. The water-legs to have vertical deflecting or circulation plates, to cause rapid currents down the outside and up the inside.

The pressure carried should be not less than 160 gauge-pounds; and, in fact, the enforced loss of fifteen pounds pressure per square inch in all non-condensing engines, even where the back pressure is clear down to the atmosphere (which it never is in any locomotive, much less in one to run at high piston speeds), should point to a still higher initial pressure, say 180 to 200 pounds.

There should be extra thick non-conducting lagging, by reason of the higher temperature (372° F.) of steam at 160 pounds.

The dry-pipe and throttle should be extra large, and there should be a superheating pipe. There should be two injectors, each of a capacity four times the evaporative requirements.

There may, perhaps, be a "blow-back valve," discharging the escape from the safety valve into the tender, for the treble purpose of quieting the noise, economizing fuel, and lessening the damage done the sheets by injection of cold feed.

The blast to be supplemented by controllable jets of superheated live steam introduced at the front and sides of the fire-box.

Cylinders, as before stated, to be 18″ x 24″.

If a D valve be used, which is not recommended, it should be of the Allen type, with 6″ travel; the upper line of the steam edges to be worked to a quarter circle, to assist in the flow of steam.

The steam chests, if a D valve be used, to be on the sides of the cylinders; or else spring relief or shifting valves to be supplied, to lessen danger from water working over.

Steam ports for D valve, instead of $1\frac{1}{2}$″ x 16″, as is usual, to be $1\frac{1}{2}$″ x 20″ at the valve seat, with passages tapering down to $1\frac{1}{2}$″ x $16\frac{3}{4}$″ at the counter bore. This is to give 25 per cent. more area with a given port opening, than is usual for steam admission at early cut-offs; giving with $1\frac{1}{5}$″ width of port uncovered, an effective open port

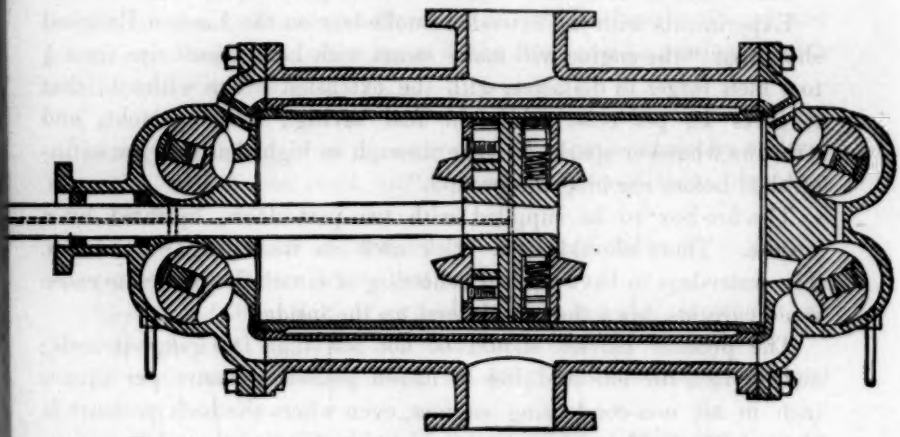


FIG. 2.—SUGGESTED VALVE AND PISTON ARRANGEMENT.

area of $1\frac{1}{5}'' \times 20'' = 24$ sq. in. at the valve seat; the maximum admission area at the counter bore being only $1\frac{1}{2}'' \times 16\frac{3}{4}'' = 25\frac{1}{8}$ sq. in. even when the port is fully uncovered.

Valve gear to be of the Joy or other radial type; preferably of such construction as to give full port opening in $\frac{1}{8}$ of its travel, stay open during the next $\frac{3}{4}$, and close during the final $\frac{1}{8}$ travel; lead and cushion to be equalized, rather than cut-off and release; and the valve gear to be so proportioned and adjusted as to do its best work at that point of cut-off most used.

On no account should any type of a link motion be used. Preferably, the steam distribution to be by four cylindrical valves across the

heads, having reciprocating partial rotation; running in oil under steam pressure, taking steam under the lip; hung on hardened steel trunnions, bearing on hardened steel bushes; motion from the crosshead. (Fig. 2.)

Piston to be spring packed with rings scarfed by a cut halfway through the width of ring, then round the ring 3″; then the other halfway through, so that as the ring wears the sides of the circumferential cuts always touch.

Piston to be lubricated by oil passing from a cup on the crosshead, through a central drill hole in the piston rod, to the centre of the top of the piston head. (Fig. 2.)

Piston rods and valve rods to be steel, and metal-packed by a spring-

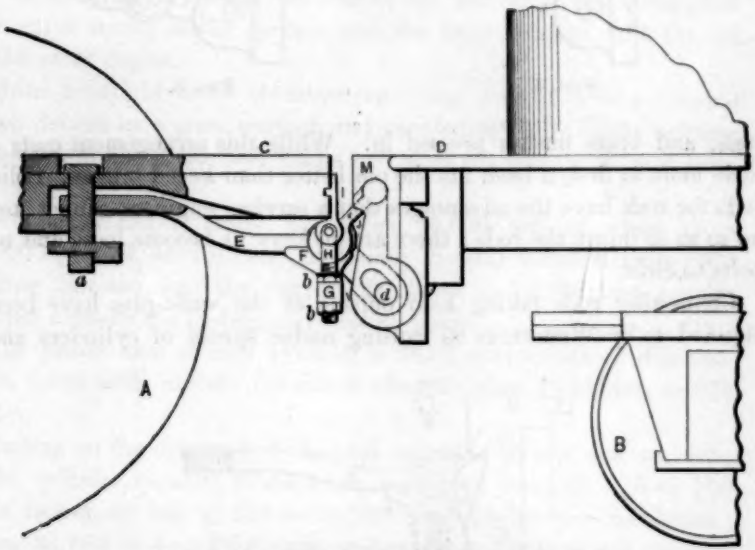


FIG. 3.—AUTOMATIC TRACTION INCREASER.

packed collar fast to the rod, and playing steam tight, though without binding, in a bored cylindrical box.

[As an alternate, Babbitt-bushed stuffing boxes, 4 rod diameters in length, bored $\frac{1}{1000}$″ larger than the rods.]

Crosshead to be of steel, of the vertical type, with adjustable phosphor bronze shoes playing on two cast iron guides of diamond section. Wrist pin, fast in the rod and playing in two bronze-bushed bearings, one at each end, in the crosshead.

Preferably, all the journals to be formed by forcing a hardened steel sleeve over a mild steel centre. All pins and cylindrical journals to be turned and ground on centres. Crank pins to be oiled by graduating cups with spring-valves which give down a fixed charge of graphited oil at each stroke and will not run dry when the crank is on centres.

Parallel and main rods rectangular section; the connecting rod largest at the crank-pin end. The parallel rods would have solid

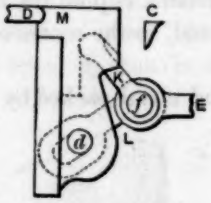


FIG. 4.

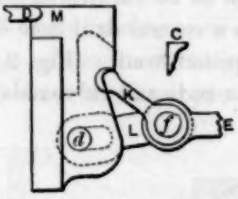


FIG. 5.

ends, and brass bushes pressed in. While this arrangement costs a little more at first, a bush fits the pin better than keyed brasses. Solid ends for rods have the advantages that a careless engineer cannot key up so as to injure the rods; there are no keys to become loose and no bolts to clear.

Connecting rods taking hold outside of the wrist-pins have been objected to by Westerners as causing undue spread of cylinders and

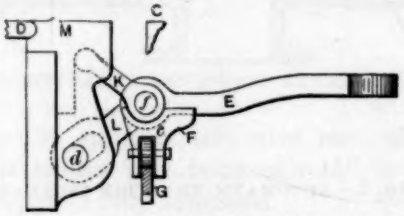


FIG. 6.

hence causing swaying. These objectors do not perhaps know that all Pennsylvania Railroad passenger engines are built with the rods taking hold of the wrist pins and give no trouble on this score. The sand box could go well down against the wheel case, as in British engines. Increase of traction on grades and curves is not to be got by sand alone, perhaps not at all by sand, but by an automatic traction increaser

capable of putting a maximum of 10 to 15 tons extra weight on the drivers, from the tender. (See Figs. 3 to 6.)

The connection between engine and tender should not be rigid, as on curves this causes the flanges of the forward engine truck and of the rear tender truck to crowd the outside rail, and the drivers and the forward tender truck to crowd the inner rail, unless the tender-truck axles are radial; which they ought to be in any case.

For the heavier curves and grades, the regular hauling engine is to be supplemented by a six coupled "bank engine," which will lie with full steam up, on a siding a few miles in advance of the tough place. The instant the train passes the siding, the bank engine starts out to catch it and gradually increasing its speed until slightly greater than that of the train, it catches the rear of the last car, which is supplied with extra strong buffer springs, and the bank is taken with the aid of the extra engine.

Main headlight to be electrical (receiving current from a dynamo direct driven by a pony engine), and supplemented by a side lighting oil headlight above it; both lamps swiveling sidewise by a lever from the cab.

Weight of engine ready for service 96,000 lbs., of which from 48,000 up to 64,000 lbs. may be equally divided between axles by a shifting fulcrum, and the rest, 48,000 down to 32,000 lbs, equally divided between the leading and trailing ponies.

The piston area of each cylinder is 254·5 square inches; displacement, 6,108 cubic inches; the driver circumference 18·85 feet, or 226 inches.

Putting on the drivers $\frac{2}{3}$ of the total weight of 48 net tons, we have, as the cylinder capacity to move the engine one inch, $32 \times 5 = 160$ cubic inches, or $160 \times 226 = 36{,}160$ cubic inches per revolution; giving $36{,}160 \div 4 = 9{,}040$ cubic inches piston displacement required per revolution.

This calls for $9{,}040 \div 254{\cdot}5 = 35{\cdot}5''$ stroke for 18″ piston diameter, or $9{,}040 \div 24 = 376{\cdot}67$ sq. in. piston area for 24″ stroke. This requires $\sqrt{\frac{376{\cdot}67}{0{\cdot}7854}} = 21{\cdot}89''$ cylinder diameter, with 24″ stroke, with the 32 tons on drivers.

If only half the total weight, or 24 net tons, were put on drivers, there would be required 6,780 cubic inches piston displacement in each

cylinder, and this we might put either 18 × 26·6 inches or 18·25 × 24 inches.

We may, then, assume that cylinders 18 × 24 require only 48,000 pounds on drivers.

Tender frame and body of steel, carried on light 33″ steel-tired wheels. Capacity of tank, 3,000 gallons; of coal-box, 15,000 lbs. Weight of tender, empty, 20,000 lbs.;* loaded, 59,000 lbs. Fitted with water-scoop.

Tender wheels "independent," or else axles capable of assuming radial positions on curves. (Fig. 7.)

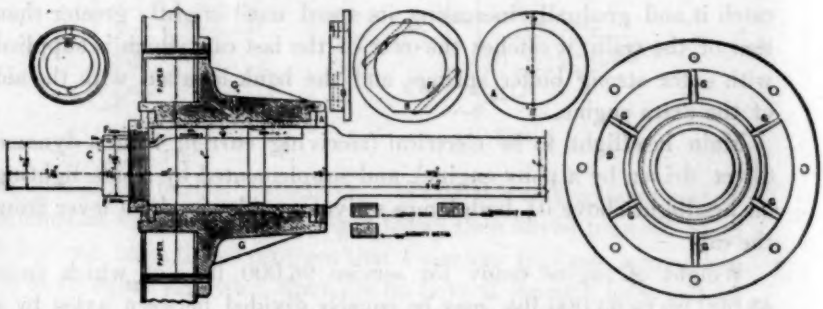


FIG. 7.—INDEPENDENT PAPER CENTERED WHEELS.

Connections between tender and forward car should be by a coupling similar to that between cars; thus making a continuous pull, without the usual jerk when the slack back of the tender is tautened.

The maximum tractive power of the 18 x 24 engine with 72″ driver is $\frac{18^2 \times 24}{72} = 108$ pounds for each pound of mean effective pressure upon the pistons.

912 miles in 18 hours is 50·67 miles per hour including stoppages. Allowing two hours for delays and stoppages, it is just 57 miles per hour while running; and counting loss from five slow-ups and startings, it makes it necessary to make 60 miles an hour right along when at full speed on levels. While this cannot be held on up-grades, dashes can be made down-grades, to keep up the average of 60 miles.

The line of the Pennsylvania Railroad proper, between Philadelphia and Pittsburg, runs (as per official figures, by the courtesy of

* This weight is about 8,000 lbs. less than most estimates, but is based upon a peculiar proposed construction.

Mr. Charles E. Pugh, General Manager), as follows: Starting at Philadelphia, and assuming as the datum line the ordinary high tide in the Schuylkill River, the gradients in feet per mile, the distances in miles, and the heights above the datum line, are respectively:

STATIONS. GOING WEST.	DISTANCES.		HEIGHTS.			GRADES.		
	Bet.	Total.	Betw. Sta. +	Betw. Sta. −	Total.	Av. ft. per mile.	Worst up over 25 ft. Leng'h	Worst up over 25 ft. Ft. per mile.
Broad Street	.....	0	.....	.....	54	.....	.....	.....
Rosemont	10	10	334	.....	388	33·4	5·	49
Malvern	10	20	151	.....	539	15·1	2·75	30
Downingtown	12	32	.....	280	259	23·3	.....	.....
Parkesburg	13	45	271	.....	530	20·9	6·	30
Gap	7	52	22	.....	552	3·14	7·9	43
Lancaster	18	70	.....	200	352	11·11	2·1	33
Mt. Joy	10	80	7	.....	359	0·70	1·8	39
Conewago	10	90	63	.....	422	6·3	0·6	42
Harrisburg	15	105	.....	109	313	7·27	.....	.....
Petersburg	105	210	356	.....	671	3·41	0·5	29
Barre	2	212	46	.....	717	23·	0·4	29
Bell's Mills	18	230	336	.....	1053	18·66	.....	.....
Altoona	8	238	118	.....	1171	14·75	.....	.....
Gallitzin	12	250	983	.....	2154	81·92	0·3	100
Bolivar	45	295	.....	1128	1026	29·06	0·4	40
St. Clair	15	310	59	.....	1085	3·93	.....	.....
Radebaugh	15	325	58	.....	1143	3·90	1·	53
Turtle Creek	15	340	.....	400	743	26·67	.....	.....
Homewood	8	348	173	.....	916	21·63	0·25	58
Pittsburg	6	354	.....	178	738	29·67	.....	.....
	354	.....	2079	2295	.....	.....	.....	.....
Philada. to Pittsburg	354	.....	684	.....	.....	1·93	.....	100

It will be seen that in the total distance between Philadelphia and Pittsburg, there is a rise of 684 feet; the highest point on the line, Gallitzin, being 2,100 feet above Philadelphia. The average gradient is only 1·93 feet per mile; but the worst grade is 100 feet, for 0·3 miles of the distance between Altoona and Gallitzin.

The following table gives the distances taken up by rising grades

(going West), from 20 to 30 feet per mile, from 30 to 40, etc. These distances are measured from an official profile, to a scale of 10 miles per inch:

Up-grades, going West.	Miles.
Over 20, and under 30 feet per mile	49·
" 30 " 40 " "	20·1
" 40 " 50 " "	11·4
" 50 " 60 " "	5·5
" 60 " 70 " "	0·
" 70 " 80 " "	0·
" 80 " 90 " "	1·2
" 90 " 100 " "	5·6
100 feet per mile	0·3
	93·1

"At first I was met with more sneers than encouragement, when I broached the subject of engines to make the transits of 900 to 950 miles in eighteen hours, including stoppages. Then master mechanics and locomotive builders, looking at the thing soberly and acknowledging the defects of existing types of engines, announced their entire ability to produce engines which would be able to do the work, month in and month out, on some ideal road—on which the grades, curves, optices and ballast were adapted to the somewhat severe requirements. But it was gravely announced that no such track existed, and that the chances were that no such track could be laid down at any price.

"Next, the concession was made that such a track could be put down, but that it wouldn't pay.

"It having been brought to the mind of objectors to the project, that such track was already down in England and did pay, the ball was tossed over again to the engine; and it was gravely (though anonymously) asserted, in a semi-practical journal, that existing engines had all they could do to knock out thirty-five miles an hour. Up steps an English engineer with figures to prove that in the London and Northwestern, freight trains, sandwiched in between fast through passenger trains, knock out forty-two miles an hour between London and Liverpool; and at present the discouragement seems to be principally

aimed at the permanent way, with a slight digression in reference to the insane Ohio laws about stopping at all grade crossings."

"The question of permanent way should be discussed from first alignment to ballast-tamping, to find out if it is not perfectly feasible and profitable to lay and maintain a track which will stand all the racket to be imposed upon it by any respectable fast train."

The matter of curves and grades requires special attention. Existing practice, particularly in the direction of curves, is particularly unpractical.

"Next comes the question of material, length, weight and section of rail; mode of splicing; ties, ballast and tamping; frogs and switches; and, lastly, bridges. As regards rail material, I suppose that it is about settled that all iron rails are to be things of the past; and that whatever metals are put down, from this point on, for any road of importance, will be of steel of some kind or another. If the advocates of iron rails have anything to say in their favor, or to the detriment of steel rails as at present used, on the ground of economy, durability and safety, I am willing to hear them; but, so far as I am concerned, we are, at present, in favor of steel. Whether it be Bessemer or Siemens-Martin, or some other present or yet unmade kind, I leave out of the question for the present.

"When it comes to lengths, it seems as though the mechanical difficulties of making and handling longer rails, even of the heaviest sections, were rapidly disappearing; and if the majority of the rails laid were in lengths of sixty feet and upwards, we would obviate the expense and risk, attendant upon the use of a great many splices. Even the most rabid advocate of patent rail joints must admit, when you get him down to it, that the best joint is no joint at all; and that the fewer joints there are, even of the most improved type attainable at any price, the less will be the wear and tear of rails, flanges and treads, breakage of springs, cutting of journals and trees, and noise, dust and discomfort to passengers.

I am aware that the question of expansion will be raised, but anticipate this by saying that the present allowance, on a thirty-foot rail, is not so much to cover the expansion as to allow for bad spring of fishplate holes."

Whatever joint is used, however, must be strongly trussed against vertical strains; and this can only be properly accomplished by a stiffening member under the flange.

"As regards sections, consideration of that ought to include both head and flange. There are those who are in favor of perfectly flat treads, and others who call for a gentle curve all the way across. Still others wish right and left hand rails. What the rail head shall be, depends, of course, upon whether the wheel treads are cylindrical or coned; and that is an oft mooted and still undecided subject (not altogether disconnected, by the by, from that of rigid *versus* loose wheels).

"The admirable reports of my friend, Prof. P. H. Dudley, point to the great desirability of increasing the flange width, with a view to lengthening the life and usefulness of wooden cross-ties; and this is well worth looking into, because it means not only cheaper ties in the end, but decreased liability to spreading of track.

"It is very certain that whatever rail section be adopted, it should be such as to comport best with the curve at the base of the wheel flanges.

"I say 'comport best;' and by this wish it very distinctly to be understood, *not* 'correspond with' but 'work well with.' I have serious doubts whether a rail and a wheel which have equal curvatures or correspond like templates, would curve well together. In this I am heretical; but it is not my fault, nor yet a criminal offence.

"Rail weight, of course, depends upon rail material, and upon the weight, frequency, speed and character of the trains passing over the line. The question of material I will assume to be settled; and will also assume that the train will consist of a well-balanced and well-equalized locomotive, having no greater weight than 33,000 pounds per driving axle, rigid wheel base of seven feet six inches maximum, and no greater speed than 350 strokes per minute; hauling a train consisting of tender and five cars, each car weighing with its load, 40,000 pounds, and having this weight distributed upon their three-wheeled trucks, twenty feet between centres. For this, I propose as a starter, a rail section with six inch flange, and giving a weight of seventy-five pounds per yard."

"There is no doubt among master mechanics, road masters, superintendents of rolling stock and master car builders, that there is an undue amount of friction between rail-heads and wheel flanges, at all times, and at all points along the track, but particularly when at high speed and on curves. Neither is there any doubt among passengers that the noise and motion are from this cause greatly increased, and the discomforts of travel thus varied and multiplied.

"It is generally admitted that the principal cause of this roughness of riding and wear and tear of rails and wheel flanges, is the primitive custom of having both wheels pressed fast upon the axle, so that whether or not the wheels upon the opposite ends of an axle are of the same diameter, or of the same 'taper' on the treads, or are round, or are concentric with the axle, or no matter whether the outer wheel on a curve has further to go than the inner, the two wheels are compelled to revolve together.

"It is needless to rehearse in detail the evil effects of this pernicious custom; but it may be useful and interesting to my hearers to present one of the more recent forms of 'loose' or 'independent' wheels, designed to allow the outer wheel when on a curve to revolve more rapidly than the inner, while at the same time preserving a higher degree of safety and not introducing undue cost and complication of parts.

"In the type herewith illustrated, the wheel itself is of the well known 'Allen' construction, with steel tires and compressed paper web or centre, bolted between steel plates, and cast iron hub, or the wheels and axles may rotate as a unit, and of course at the same rate, in the regular outer boxes; or one wheel may revolve with and the other on the axle. Lubrication of the large inner bush and journal is insured by oil passages, *F*, *F*, leading from the oil box to an oil chamber *E*, cut in the journalled wheel seat. The Babbitted bush of the bore is held against end motion by circumfluential ribs, and is flanged up at the ends; the inner flange of each wheel being protected by a wrought iron collar, *A*, butting against the shoulder of the wheel seat, and the outer end having also a wrought iron collar *B*, one and one-half inches long, threaded upon the axle between the outer journal *C*, and the wheel seat journal. These threaded collars *B* are held from turning by pins *F*, *F*, rivetted at each end. The hubs *D*, are each strengthened by six ribs, *G*, *G*, etc."

DISCUSSION.

MR. W. BARNET LEVAN:—Mr. Grimshaw has stated that he proposes to dispense entirely with the link motion. Now, if dispensing with links entirely what will be his position in the event of having to run on a siding or have a break-down. How does he expect to back his engine?

MR. GRIMSHAW:—I don't know what is meant by this question. I simply cannot answer it. It assumes that the Joy is not a reversible gear, or is more easily crippled than the link. As a matter of fact the Joy is a reversible gear, and I have no knowledge that it is more easily crippled than the link, owing to the fact that I do not know of any of them having been crippled.

MR. LEVAN:—Where will you find the Joy link motion in use in this country? To my knowledge there are only one or two in use on locomotives, and they are very unsatisfactory.

MR. GRIMSHAW:—I have seen letters from master mechanics of several American roads, commending the Joy gear, and stating that they purpose adopting it. I have elsewhere answered the question as to its success on the Reading Railroad, and will only add that Mr. Joy says: "When Mr. Paxson sent me his blue print I saw it would only injure the gear. I told him the centre fixing and overhang would never do. If they *will* make bad designs failure is a matter of course."

MR. GEORGE S. STRONG criticised one point on the locomotive. Mr. Grimshaw proposes for fast trains, *i. e.*, the pony, or two-wheel truck as a leading truck, stating that he feared it would not be capable of keeping the rail if detached from the rest of the locomotive, as is a four-wheeled truck, which will keep the rail and forms a truck within itself, at the same time it presents two wheels to take the blow of striking a curve, while the other only presents one. He was afraid that a pony truck for very high speeds would be more liable to break loose from the locomotive and swivel across the track and wreck the whole engine. He also described a locomotive engine with extended smoke-box and other special features, now being built for the Lehigh Valley Railroad Company.

MR. GRIMSHAW:—Engineers on the Lehigh Valley Railroad, quoted by Mr. Strong as one on which a two-wheeled truck would not take curves at high speeds, say that they *do* take them, and safely. The Denver and Rio Grande Railroad runs pony truck engines at forty-five miles an hour perfectly safely on their curves. It only requires that the pony wheels be equalized with the front drivers, as now done with perfect success on the Denver and Rio Grande Railroad.

MR. J. W. NYSTROM:—I fully appreciate the importance of Mr. Grimshaw's paper, and believe it feasible to run a train with the high speed he proposes. I would ask that the diagram of the proposed loco-

motive be reproduced on the screen for further remarks on the same. [The diagram was reproduced, and Mr. Nystrom continued.] The greatest difficulty with the locomotive has always been its incomplete combustion, and consequently waste of fuel, by throwing out smoke and sparks, setting fire to houses and other combustibles near the railroad. This evil is caused by an excessive draught through a thick fire on a too small fire-grate. I spoke on this subject at a meeting of the Institute some twenty years ago, and remarked that the locomotive engineers are behind the times in steam engineering.

The principal defect in the locomotive consists in the smallness of its fire-grate, which is confined between the driving-wheels, and it cannot be conveniently increased in length.

In order to overcome this defect, Mr. Wootten placed the fire-grate above the driving-wheels, where there is space enough to make it of the required or proper size. Mr. Wootten's arrangement was illustrated and explained at a meeting of the Institute a few years ago, when I remarked that the fire-grate should be placed over the trailing truck, instead of over the large drivers, which raises the boiler up too high. My suggestion was not considered feasible by some members of the Institute. Now, Mr. Grimshaw produces a sketch of a locomotive with the fire-grate above the truck, but he still confines the width of the grate between the driving-wheels. By moving the boiler back a little, so that the furnace will clear the driving-wheels, the fire-grate can be made wide enough for proper combustion without excessive draught, and thus avoid smoke and sparks, which will result in economy of consumption of fuel.

Mr. Grimshaw proposes to make the fire-grate about 10 feet deep by 4 feet 4 inches wide, making 43 square feet grate surface. It is very difficult to keep a clean and even fire upon a grate 10 feet deep; but if the fire-box is cut off so as to clear the driving-wheels and make the grate 9 feet deep by 7 feet wide, making 63 square feet grate surface; or, perhaps better, to make the grate 8 feet square, or 64 square feet surface, the boiler would be more economical on fuel, and of much greater steaming capacity.

About the cylindrical valves of which Mr. Grimshaw speaks, I would ask if he means piston-valves?

[Mr. Grimshaw produced a drawing of the valves on the screen, to which Mr. Nystrom remarked]: They are Corliss' valves, but Mr. Grimshaw says that he will run the valves in oil under steam pres-

sure, and I cannot see how that can be done without driving the oil into the cylinder.

Mr. Nystrom added: There are many details proposed by Mr. Grimshaw which, whether good or not, have no important bearing on speed of the train which is a function of power, and that additional power can be obtained by proper arrangement of the fire-grate, as before stated.

A small fire-grate requires a stronger draught and thicker fire, which is extravagant of fuel, whilst a larger grate surface requires less draught and a thinner fire, by which the combustion will be more complete. I may refer to a case where I constructed a steamboat with compound engines, and was not allowed to make the fire-grate as large as I desired. After the boat had run about a year the boiler was taken out, and another one with larger fire-grate was substituted, which resulted in better steaming capacity with greater economy of fuel, although the amount of heating surface was the same in both boilers. I cannot see the economy in creating the draught by superheated live steam, instead of by the exhaust, as proposed by Mr. Grimshaw.

Mr. LeVan:—Mr. Grimshaw has stated that a large grate surface is essential for the rapid production of steam for fast running locomotives.

It does not seem to have occurred to them that any boiler may be economical or otherwise, in respect to fuel, according to the rate of evaporation, and that in the case of a locomotive boiler this rate is of necessity almost always varying. For a given rate of evaporation I may have with equally good reason a large fire grate of 58 square feet and a slow rate of combustion, as in the case of the Wootten boilers, as used on the Bound Brook route; or, a small grate, 35 square feet, as in Class "K" Pennsylvania Railroad, and a quicker combustion. In both these cases, from reliable information, the same amount of fuel is burned in the same time and performing the same service. This shows that the same quantity of heat is taken up by the water; consequently, so far as mere economy of fuel is concerned, one boiler will be as good as the other. As for *heating surface*, this has really nothing to do with grate area, but merely with the quantity of fuel burned in a given time. "Heating surface," or rather the fire-box plates or flues, through the substance of which, heat is transmitted, is only effective in proportion to the difference of temperature on the opposite side of the plate.

Numerous experiments and researches have shown that the thickness of the plate has no influence on the coefficient of conduction; thus the thin tubes of tubular boilers transmit no more heat per surface unit than thick plates of a fire-box boiler.

In high speeded locomotives the engines are the greatest drawback. Taking the indicator diagrams of the Wootten and Class "K" engines, you will find the former to show over eight pounds average back pressure before compression commences, while the latter shows but six pounds, when performing the same amount of work and running at the same speed; and the initial steam pressure in the former being 84 pounds, with a boiler pressure of 123 pounds per square inch, and the latter 120 pounds initial, with a boiler pressure of 140 pounds per square inch. The former only realizes 55, and the latter 63 per cent., whereas if they were up to the best stationary practice they should at least show 90 per cent. efficiency.

As regards the Joy valve gear, so far it does not seem to have made much progress in this country. I know of only two in use on locomotives, and they do not seem to give satisfaction; the plan adopted by Mr. Strong is a much better arrangement, as I understand it.

Mr. Grimshaw also says the smoke-box should be of the "extended" class. Now, I maintain, in the first place, that an extension of the smoke box to a length of over say 42 inches from tube-head is essentially and radially wrong and injurious; further, that if the fire-box is of proper size and construction it is *needless*, and if not, it is, as Mr. Parry of the Baldwin Locomotive Works said about the swing trucks "helping to remedy a wrong by making another wrong." It is nothing more or less than a receptacle for unconsumed fuel carried through the tubes, and the claim that it can have any effect whatever (other than a *detrimental* one) on consumption of fuel, evolution of smoke, or steaming qualities of boilers, is, on its face, absurdly false.

No practice was or ever can be successful which runs counter to a well settled theory, and this does violence to the plainest laws governing the movement of fluids, and to their action, as observed in every boiler. We do not put a twelve inch elbow on a six inch water pipe, and if we expand the smoke box of a locomotive to hold sparks, it is impossible, to say the least, that it shall produce any *beneficial* result on combustion, and I claim, as a matter of fact, that it does the reverse.

The experiments with the Shaw locomotive proved this conclusively.

With it she would not give satisfaction; as soon as it was removed and the old arrangement substituted, everything went lovely. The fact is if the deflector plate was removed the result would be quite different. With a deflector and a forty-two inch extension, the results are the same as with a seventy-two inch extension.

It is a notorious fact that locomotives do *not* steam as well after the substitution of the extended smoke stack as before, as I have been repeatedly told by engineers, who thought they could speak the truth without danger of removal. Several of the engineers of the New York West Shore and Buffalo Railroad said that their boilers were steaming poorly from the fact of being handicapped by the late Howard Fry with these abortions, and that it was all they could do to get 90 pounds out of them when they ought to be at least 130 pounds. The majority of engineers on the Pennsylvania railroad will corroborate these statements, when they can do so without risk of losing their positions.

The only logical and common sense plan is the return of the sparks back into the fire-box as done by Pike's system.

MR. GRIMSHAW:—I beg to differ diametrically from Mr. LeVan as to the value of large grate surface. Properly managed, and so long as there is sufficient heating surface in flues, large grates give the best economic results. As competitive tests between the Wootten and the Pennsylvania Railroad standard type of locomotives are now (May 12) being conducted, the public will soon have interesting figures in this connection. Grate area of necessity gives larger fire-box heating surface.

Thin tubes give quickness of steaming power in starting, and quick recuperative power after hard pulls on curves and grades.

Private advices from England show the Joy gear to be giving the highest satisfaction on the best roads. The modification thereof, adopted on the Philadelphia and Reading Railroad, was, I understand, protested against by Mr. Joy and its failure predicted.

I took careful advice as to the extended smoke box. It may be "remedying an evil at the wrong end," but sometimes we do not have choice of ends. It is better to remedy an evil at the worst end than to refuse to remedy it because that is not the end we would prefer. The figures on nearly every road where it has been adopted, show saving by its use. The statement that "no practice was ever or could be successful which ran counter to a well settled theory" is too much at variance with the history of progress to need any detailed refutation.

SURVEYS FOR FUTURE WATER SUPPLY.

[From advance proof-sheets of the Report of Col. WM. LUDLOW, Chief Engineer of the Water Department of the City of Philadelphia.]

The increasing pollution of the Schuylkill, whence the main water supply of Philadelphia is derived, and in particular the occasional exacerbation of its unwholesome symptoms to the degree of rendering it totally unsuitable for ordinary purposes, have been already referred to, but the discussion which for a generation has been maintained with more or less earnestness and intelligence, has resulted only in confusing the subject with multiplied and variant suggestions, and in the absence of exact and carefully determined data, could not in the nature of things reach definite conclusions.

Not only has the quality of the water itself been the subject of dispute, but the widest diversity of opinion has been expressed as to the means best adapted to amend existing evils and to make suitable provision for the future.

It seems strange that, in a matter of such vital economic and social importance, this very contrariety of opinion should not have called attention to the one essential point, which had, moreover, been urged by competent advisers, viz.: The necessity for such thorough scientific investigation based upon the actual ascertainment of facts, as should eliminate doubt, and simplify the consideration of the problem by clearly determining its real conditions.

Sooner or later all cities are brought face to face with the water problem, and even when it has been thought that a solution has been reached, the development of industries and the growth of population out-run the provision which it was believed would suffice for long periods, and call for constant watchfulness and care to meet the growing demands.

In the case of Philadelphia, the problem—notwithstanding an apparent simplicity of conditions—is more than ordinarily complex. The Schuylkill brings the water to the heart of the city, and even furnishes the power with which to pump it, and it was therefore natural and proper enough to regard it as the main reliance. But the valley of the Schuylkill has peculiar features. At its source, the water—to a large extent the drainage of the coal measures—is charged with the acids resulting from the decomposition of the iron pyrites, and this

excess of acid is still further increased by the great development of the mining industries. Farther down, the affluents drain a limestone region, and the commingling of the acid and alkali tends to neutralize both and to impart a certain degree of potability to the stream. As was pointed out long since, the water of the Schuylkill is an artificial product, depending for its quality upon a nice balance of chemical constituents, the undue preponderance of either of which would injuriously affect its use—the acid by destroying boilers and water-pipes, the lime by causing scale and rendering the water too hard to be acceptable.

This chemical balance has been hitherto sufficiently well maintained to give no great cause for complaint, but the pollution of the stream by the growing population and the industries of the valley, has become a most serious feature.

The Schuylkill is the natural drainage outlet and sewer for the entire region traversed by it, and unless means can be found and applied to effectually cut off or thoroughly neutralize the multiplied sources of pollution, it is hopeless to consider it available in the future for drinking purposes.

To accomplish this, however, both legislative action and costly engineering works will be required, and the discussion of these must be deferred until the investigation now in progeess shall have fully disclosed their character and extent.

Leaving aside the Schuylkill proper, it then remains to consider whether or not one or more of its affluents could be made to meet the necessary requirements. Of these, the Perkiomen alone is of such character as to promise good results, and in consequence the project of impounding the Perkiomen waters and bringing them to Philadelphia by a gravity conduit has heretofore presented itself as a plausible one, and been urged with more or less earnestness. In the absence, however, of such accurate data as must be obtained, it has been impossible to do more than accept estimates and opinions as a basis of argument, and there now appears good reason to believe that in respect of both quantity and quality, the Perkiomen supply would prove deficient.

Should it result that neither the Schuylkill nor its main affluent can be securely relied upon for the future, the Delaware must be considered, and this aspect of the case has hitherto been scarcely more than glanced at. Numerous suggestions have been made, but again the lack of precise and authentic information has crippled investigation and made discussion futile.

The estimated cost of every one of the Delaware projects has been so large as to discourage their consideration, but if the best results are to be attained, the investigation must be made.

For a gravity supply, the Delaware water must be taken somewhere in the vicinity of the Gap, since it is not until that point is reached that the elevation of the stream is sufficient to give the necessary fall. For a supply by pumping to a conduit, points nearer by offer themselves. The Delaware, too, has affluents which might be impressed into service, at least to diminish the necessary pumping.

A third possible source is the Upper Lehigh, whose waters in respect both of purity and altitude, present most favorable conditions, although the distance is great and the minimum flow less than is required for a full supply.

The ideal source is one whose swift waters, drained from a wilderness barren of mines or agriculture, and which the laws of nature will effectually guard from defilement by population or industry, can be diverted from the living reservoir of their rocky channel, and through an aqueduct of reasonable length, be delivered to the city receiving basins, as limpid, palatable, and free from contamination as when tumbling freely in their native bed.

Of all the sources available, the Upper Lehigh comes nearest to this standard, and the Upper Delaware,—whose greater flow is ample for all needs,—comes next.

It happens, however, that ideals are rare of attainment, and in the present case, economic considerations intervene to counsel caution, and compel the fullest and most careful investigation before a decision be made, but it cannot be denied that Philadelphia, with all her fortunate conditions, is doubly favored in having at her command, whenever she shall choose to claim it, a superb source of water supply which for generations to come will fulfill every requirement.

In investigating the Delaware project, some unexpected features were developed. It was necessary in running the conduit lines to the Gap, to take advantage of the valley itself to pass the South Mountain, and in doing this, Point Pleasant,—about half-way between Trenton and Easton, and 30 miles from Philadelphia,—was readily seen to be the most advantageous point at which to reach the valley. The conduit line to this point proved to be much more favorable than was anticipated, largely reducing previous estimates, and furthermore, the quality of the water in the Delaware at Point Pleasant was found to

be extremely good,—better, in fact, than that of any of its affluents,—and almost comparable with the water of the Gap.

The conduit line to Point Pleasant intercepts the Pennypack and the Big and Little Neshaminy, and when nearing the Delaware valley taps also the Tohickon. It results from this combination of circumstances that the Delaware project might be considered as terminating temporarily at Point Pleasant, where pumps could lift the Delaware waters to the conduit and send them in to the Wentz Farm and the proposed Cambria Basins at an elevation of 165 feet. Furthermore, the waters of the intercepted affluents could be used to decrease the pumpage, and in fact for the greater part of the year, would, in all probability, furnish the full amount required.

An aqueduct northward from the Wentz Farm Basin would therefore come almost immediately into service by bringing in the supply from the several streams as they were successively reached, and the Point Pleasant Pumping Station would continue to furnish any amount of excellent water while the construction of the conduit should be proceeding towards the Gap.

The unexpected purity of the Point Pleasant water is due to two causes: First, the considerable aeration and consequent purification the Delaware waters are subjected to by flowing swiftly in a natural channel, and over numerous riffs and rapids; and secondly, the partial exclusion of the low water drainage of the Lehigh by means of the canal on the right bank of the Delaware, which absorbs the summer flow of the Lehigh when it is most highly charged with the sewage of Easton, Bethlehem, and other cities in that valley.

The problem of the Future Supply of Philadelphia, therefore, presents itself under three aspects:

First—The practicability, the requisite means, and the cost of redeeming the Schuylkill, and so effectually guarding it against future pollution as would justify the city of Philadelphia in depending upon the use of its waters for domestic and manufacturing purposes.

Second—The determination of the quality and quantity of the waters that can be reliably obtained from the valley of the Perkiomen; and,

Third—The cost and other particulars of the Delaware project—accepting Point Pleasant as a half-way station, and looking to above the Gap for a gravity supply.

As an alternative to this, the excellent suggestion is advanced by

Mr. Hering, of bringing the waters of the Upper Lehigh into the Upper Perkiomen—thereby increasing the quantity and improving the quality of the latter.

It will be seen by any one conversant with the subject, that it has grown to great, and it may be said, unexpected proportions. The area of country to be examined, whether by accurate surveys or reconnoissances, is larger than has ever been attempted in this country; and, in this connection, a comparison of the necessary extent of the Philadelphia surveys with those made by other cities, will be instructive.

New York, with a topographical area to be covered of about 2,000 square miles, of which 100 were mapped and 250 were carefully reconnoitered, has, since 1875, spent an average of over $30,000 annually, or about $250,000.

The Baltimore surveys cost about $15,000, but only the Gunpowder project, which has since been successfully completed, was seriously considered, and the length of the conduit was seven miles only.

In Boston, the areas surveyed were about 50 square miles, and examinations were made of a total of about 5,500 square miles. The length of conduit line was 15¼ miles. The investigation occupied about three years, and cost $60,000.

The Philadelphia investigation will require careful surveys of about 468 square miles, conduit lines about 183 miles, and a general examination of about 6,500 square miles.

The work which has so far been accomplished is excellent in character, large in amount, and economical in cost; and it is of the greatest importance that it should be carried to completion with the parties now fully equipped and trained to their work.

The total expenditure that will be required cannot yet be determined. The investigation, owing to an unexpected balancing of various advantages and disadvantages, physical and economic, has assumed proportions that were not at any time heretofore contemplated. But it is work that is absolutely essential to an accurate and reliable solution of the problem, and I feel no hesitation in saying, that whatever necessary expenditures are incurred will be amply repaid in the end.

The expense of maintaining and supervising the work is about $2,500 per month, and this year will probably see the greater part of the field work fairly advanced to completion.

The results are too important, and the consequences of a failure to

obtain all necessary information would be too serious to allow me to feel any hesitation in asking for such funds as may be required to complete the investigation.

The reports from Dr. Leeds and Mr. Hering furnish a full account of the operations under their respective directions, and contain information of the greatest interest and value.

The Department was especially fortunate in securing the services of these two gentlemen, both of whom are well known in the professional world in their respective branches of inquiry and have evinced the highest interest in the important labors entrusted to them.

The circumstances are such as to necessitate a continuance of the investigation in order to cover the entire field, and to reach such reliable results as shall justify the preparation by the Department of final estimates and recommendations; but the conditions are now thoroughly understood, many points of doubt have been eliminated, and the work can proceed with clear conceptions towards a determinate conclusion.

The varying character of the several streams at the different seasons makes it necessary to establish minimum as well as average data, and observations extending over at least a brief term of years are required.

Analysis has so far confirmed opinions formed from engineering and physical data, and Dr. Leeds is enabled to reach the preliminary conclusions expressed in his final remarks, viz.: as to the advisability of ceasing to pump water at the Kensington Station, and as to the necessity for immediate measures to guard the Schuylkill from pollution, if its use as a source of supply is to continue. Inasmuch as any modifications of the existing system must, under the most favorable circumstances, require for their completion a period depending upon the means which can be made available for this purpose, the conclusion of Dr. Leeds as to the frequent and recurring non-potability of the Schuylkill, call for most serious consideration on the part of those upon whom is laid the responsibility of making adequate provision for the necessities of this great city.

Mr. Hering's report contains a careful *resumé* of all publications upon the questions of future supply, and gives a detailed account of the work of the surveying parties.

The plan of operations was laid down after a careful preliminary examination of the subject, and from time to time fresh or modified instructions were given as the work extended.

Great care was exercised in selecting the gentlemen to conduct the field work, and the results are such as to reflect high credit upon all engaged.

It is believed that the greater part of the field work of the survey can be completed before the close of this year, and the entire investigation concluded at a total cost not much in excess of the expenditure made by Boston, to cover an area of very much less extent.

Analysis of Spectral Rays.—Cornu has published the result of his investigations upon the *a* group of spectral lines, which was discovered by Brewster and is situated between *C* and *D*. Its great increase of intensity when the sun approaches the horizon indicates its telluric origin; but it is not due to the vapor of water. Cornu finds that it contains lines of three different kinds: 1. Metallic lines of solar origin, recognizable by their oscillation. These lines are gray, broad, and blurred upon the borders, while the telluric rays are black and sharp; 2. Dry, atmospheric lines, forming two unequal series of channelled double rays. This group reproduces, line for line, the arrangements of the telluric groups *A* and *B*, so that the three groups should be attributed to the same element, which is probably oxygen. M. Egoroff finds that the reciprocals of the wave lengths of the homologous rays, in the three groups, are nearly in arithmetical progression; 3. A third group is formed by lines which have a considerable intensity when the sun is near the horizon, and which disappear almost entirely when the atmosphere is cold and dry. The grouping of lines in harmonic ratio, noticed by M. Egoroff, was first published by Chase, on August 23, 1877 (Proc. Am. Phil. Soc., xvii, 109).—*Chron. Industr.*, Feb. 24, 1884. C.

New Paint.—At the military port of Brest, a mixture of zinc white with zinc chloride has been used for some time, with good result, in painting wood and metals. It becomes very hard, and can be washed or brushed without injury. It should not be applied, however, in rainy or frosty weather, as it then becomes mealy and scales off easily. Chloride of zinc is not the only salt which possesses the property of forming a mastic by its mixture with zinc white. Sorel long ago indicated the proto-chlorides of iron, manganese, nickel and cobalt as good bases for mastic. After having verified his views, the authorities of Brest

have extended his experiments, and have shown that the sulphate and nitrate of zinc, the sulphate, nitrate and chloride of iron, and the sulphate and nitrate of manganese form good mastics and paints with zinc white.—*Chron. Industr.*, March 2, 1884. C.

Parchment-Paper Packings.—A German mechanic engineer observed that damp parchment-paper, when strongly compressed, forms a homogeneous and unctuous material, which has great rigidity and toughness. Finding, moreover, that when exposed by its cut edges to the friction of a smooth metallic surface it undergoes but an insignificant amount of wear, he took out a patent for the manufacture of journal boxes from compressed parchment-paper. One great advantage of the material consists in the lubrification which can be produced by water alone; a light greasing with oil at the outset would be sufficient to prevent rust.—*Les Mondes*, March 8, 1884. C.

Underground Telegraph Wires.—The bulletin of the French Telephonic Society calls attention to a complete interruption on most of the telegraphic lines, for 48 hours, caused by a violent tempest. The subterranean wires which united Paris with the principal cities of Northern and Eastern France worked, however, without interruption, so as not only to satisfy all their normal traffic, but also to supply much of the deficiency arising from the failure of the other lines. Had it not been for the underground wires, Paris would have been entirely cut off from all telegraphic communication with other points.—*Les Mondes*, Feb. 23, 1884. C.

Calling Dogs by Telephone.—In December, 1877, during some of the earliest experiments with telephones in France, one experimenter held a receiver near the ear of a dog, while another, who was in a distant room, called the dog by name several times. At each call the animal turned in surprise and assumed a most comical look of amazement. A similar occurrence, in New York, has been mentioned in some of the journals. A lost dog, having a receiver placed near his ear, recognized the call of his master, and replied by joyous barkings and licking the apparatus, from which he seemed to expect to see his master come forth.—*Les Mondes*, Feb. 23, 1884. C.

Ancient Metallic Architecture.—Charles Normand, the architect who restored the Vendome column, has read a paper before the

French Engineering Society, upon the employment of metallic architecture before the Christian era. He presents evidence of its use, not only in the details of public and private edifices, but also in the erection of buildings in which nearly the entire structure was of metal. Columns of iron and bronze were used in many of the Assyrian and Jewish monuments, and some metallic beams of the Roman Pantheon were remaining in the sixteenth century. Metallic joists and terra-cotta panels were used in ceilings, in the same way as in many modern structures.—*Chron. Industr.*, March 9, 1884. C.

Modern European Flint Weapons.—Two tumuli have lately been explored in Piat, Côtes du Nord. In the smaller there was a medal, with a portrait of Maximian, who shared the throne with Diocletian from 284 A. D. to 305 A. D. It was placed under a flat stone, which was evidently designed for its protection. Near it was an urn of graceful outline, containing bones and ashes. In the other tumulus, the explorers found a sword, a number of daggers, one of which was ornamented with golden studs, and about fifty flint arrows. It appears, therefore, that flint was employed, together with metal, as late as the third century of the Christian era.—*Les Mondes*, Feb. 16, 1884. C.

Sinking Shafts in Quicksands.—M. Haton de la Goupillière read a paper before the French Société d'Encouragement, upon the Poetsch method of sinking shafts in watery soils and quicksands. A series of hollow iron tubes, with cutting sabots, is sunk in a circle around the well. Within these, other smaller tubes, pierced with numerous holes, are placed. Through the inner tubes a refrigerating liquid is forced, in a continuous current, until the soil in the critical neighborhood is frozen, and the intrusion of the sand and water is prevented so as to allow the sinking of the main tubular shaft.—*Chron. Industr.*, March 16, 1884. C.

Crab-Apple Hedges.—A skillful French horticulturist writes to the *Gazette des Campagnes*, that nothing is more suitable for a living hedge, more vigorous, or of a more rapid growth, than the wild crab-apple. Two-year old stocks should be set out, either in autumn or in spring; a good spring ploughing enlivens the growth and checks the weeds. A second ploughing, in the month of August, is also necessary, and if there is garden mould or manure to be added, so much the better. The young plants should be allowed to grow, without prun-

ing, for two years. In the third year they should be cut down to about 10 centimetres (4 inches) from the ground, and then the shoots will develop in all directions with remarkable vigor, the strongest growing straight upwards, the weakest creeping upon the ground and intertwining, so as to form a barrier, which will be impenetrable even by the smallest animals. When the hedge is once started, it will only be necessary to trim the top to the desired height as often as is needful, and to dig about the roots whenever weeds threaten to exhaust the soil.—*Les Mondes*, March 15, 1884. C.

Electric Equilibrium.—Gore has investigated the degree of force required in an electric current in order to hinder a chemical combination. To show that the chemical and electric forces can be balanced, he takes a solution of silver and of cyanide of potassium and plunges into it two electrodes, one of silver the other of platinum. The silver electrode tends to dissolve, with an energy which depends upon the richness of the cyanide and its temperature. This tendency is counteracted by passing a current through the electrode, the intensity of which is measured by the ordinary methods. When the current arrests all chemical reaction the two forces are in equilibrium. This method, simple as it is and susceptible of a great variety of applications, is very fruitful in results and opens to science a new field for the measurement of chemical forces.—*Les Mondes*, April 21, 1883.

Frontal Electric Photophore.—Messrs. Hélot and Trouvé have presented to the French Academy the description of a medical illuminating apparatus, to which they give the above name. It is composed of an incandescent lamp, enclosed in a metalic cylinder, between a reflector and a converging lens. The apparatus, which is very light, is applied to the forehead, and furnishes an intense glow, the field of which can be varied by a slight displacement of the lens. A battery of bichromate of potash furnishes the electricity. The light can be used for illuminating the natural cavities or a deeply situated field of surgical operation.—*Comptes Rendus*, April 16, 1883.

Explosive Waves.—Berthelot and Vieille have investigated the enormous living force and pressure which are propagated in explosive waves by the change of chemical constitution. They observed in the oxyhydric mixture a velocity of 2,841 metres, while that of the sonorous wave is only 514 metres. With the oxycarbonic mixture the

velocity of the explosive wave is 1,089 metres, while that of the sonorous wave is only 328 metres. The explosion produces a single and characteristic wave; but the sonorous phenomenon is due to a periodic succession of waves. The excess of *vis viva* communicated to the gaseous molecules by the act of chemical combination, represents the precise amount of heat which is set free in the reaction. The explosive wave is propagated uniformly and its velocity is independent of the pressure, as well as of the material and diameter of the tubes, above a certain limit. The velocity constitutes, for each inflammable mixture, a true specific constant, the knowledge of which possesses great interest, in view of the theory of gaseous movements as well as its applications in the use of explosive materials. The conclusions of the research are applicable not only to mixtures of explosive gases but also to solid and liquid explosive systems, provided they are wholly or partially transformed into gas at the moment of explosion.—*Ann. de Chim. et de Phys.*, March, 1883.

Natural Harmonies.—On October 20, 1880, W. de Fouvielle, M. Perron, and Capt. Chayru made a remarkable balloon ascension in England and heard musical sounds while they were floating, at sunset, at an elevation of several hundred metres above the ground. In a large forest, situated in the West of France, during warm and calm summer days, when the ocean of verdure is the seat of a rapid evaporation, a harmonious sound is often heard in the air, which is well known to the peasants and which they call the "song of the forest." Abbé Gastoin observed that the sonorous vibrations of the æolian harp are not heard when the air is agitated by the wind, but only when it is calm, and harmonic currents are produced by changes of temperature. Tyndall's experiments in radiophony seem to furnish a satisfactory explanation of all these phenomena.—*Rev. Scientif.*, April 21, 1883.

Dilapidation of Bricks.—The destruction of brick walls is generally attributed to the influence of heat, dampness and frost; but according to recent observations the true destroyer appears to be a microscopic organism, and the action produced by temperature is of secondary importance. M. Parize has examined with a microscope, the red dust which is produced by the crumbling of the bricks, and he found that it contained a large quantity of minute living animalcules. The magnifying power of the instrument was 300 diameters.—*L'Ingénieur; Chron. Industr.*, April 22, 1883.

Delauney's Earthquake Predictions.—Perrey, Mallet and Delauney have all made very instructive researches upon earthquakes, availing themselves of records which extend over more than a century, and endeavoring to deduce data for predicting the times of recurrence. Daubrée thinks that the statistical statements are insufficient to justify such prediction. Movements of feeble intensity are felt almost every day, in many parts of the globe. Even if the attention is directed almost exclusively to violent shocks, the data are necessarily incomplete, whatever may be the care and the ability of the observers. Europe does not form one-fiftieth of the surface of the globe; vast parts of other continents may be shaken without our knowledge; and the ocean, which covers three-quarters of the globe, must be subject to frequent and numerous shocks, which are almost always unnoticed. One might as well claim to establish a systematic statement of the meteors which fall annually upon our planet, of which more than ninety-nine per cent. remain unknown to us.—*Comptes Rendus*, Oct. 1, 1883. C.

Cause of Earthquakes.—Daubrée, in discussing the recent earthquakes in Europe and Asia, presents many objections to the theory of falling rocks in internal chasms, and thinks that all the phenomena can be satisfactorily explained by the action of superheated steam. He refers to the well-known craters of explosion, such as Lake Pavin, in Auvergne, where the stratified rocks have been cut sharply through, as if by a punch. The modern experiments with gun-cotton, nitroglycerine, and dynamite, have often shown pressures of more than 6,000 atmospheres, and produced results which could hardly be wrought by the pressure of weights 600,000 times as great as that of the explosives. Superheated steam, when set in movement by such simple mechanism as nature often presents, would account for all the action of earthquakes, their violence, their frequent succession, and their recurrence in the same regions for many centuries. It also explains the predilection of earthquakes for regions where there are numerous faults, especially if the dislocations are recent. Earthquakes appear to be, in many instances, like subterranean volcanic eruptions which are smothered because they find no outlets. The motive power of gases, of which we see the gigantic effects in the solar jets or protuberances, appears also to be considerable enough beneath the surface of our planet to explain all the effects of earthquakes.—*Comptes Rendus*, Oct. 8, 1883. C.

Solar Protuberances.—Faye suggests the great probability that hydrogen, when escaping rapidly into the rare medium which surrounds the photosphere, is at first chilled, on account of its enormous dilatation, and becomes invisible to the spectroscope. Afterwards, under the action of solar radiation, it is reheated in various places, so as to be seen by our instruments. An observer, who should return after a half hour's interval, to contemplate the phenomenon, would find the protuberance wonderfully enlarged, without the hydrogen having been required to traverse enormous spaces in the meanwhile. Father Secchi saw small isolated clouds, forming and growing simultaneously without visible connection with the chromosphere, apparently in the same way as the clouds which are formed in our own atmosphere, from the vapor which already exists in the air, but which is latent and remains invisible, until a local cooling, or a change of pressure, determines its condensation.—*Comptes Rendus*, Oct. 8, 1883. C.

General Law of Congelation of Solvents.—The fact that water congeals at a lower temperature, when it holds saline matter in solution, than when it is pure, was known during the last century. In 1788 Blagden showed that the lowering of the point of congelation was proportional, in many cases, to the quantity of matter dissolved. Subsequently Despretz, Leon Dufour, Rudorff, and de Coppet have verified Blagden's law; and Rudorff has explained various anomalies by the fact that the dissolved salts are some of them anhydrous, while others are hydrates. Prof. Raoult, of Grenoble, has experimented upon various groups of mineral and organic substances, in order to fill the lacunæ which have been left by previous investigators, and has arrived at the following conclusions: 1. Every solid, liquid, or gaseous body, when dissolved in a definite liquid compound which is capable of solidification, lowers its point of congelation. 2. In two specimens of any body, the purest is the one which solidifies, or rather, which melts at the highest temperature. 3. The atomic or molecular lowering is sensibly constant for each solvent. 4. In weights of different solvents which are proportional to their atomic weights, the lowering at congelation is independent of the nature, both of the solvent and of the body dissolved.—*Comptes Rendus*, Oct. 15, 1883. C.

Electric Aërostat.—A. and G. Tissandier made their first ascent with their electric balloon, on October 8, 1883. The balloon was 28

metres long, and 9·20 metres in diameter at its centre. It was inflated with hydrogen gas, nearly pure, and having an ascensional force of 1,180 grammes per cubic metre. The weight, including the electric motor and all its accessories, was 704 kilogrammes. When the helix was driven with 180 turns per minute, it yielded a work of 100 kilogrammetres and drove the balloon through the air so as to produce a brisk wind. When the head of the balloon was pointed towards the wind it could be kept immovable, although the wind was blowing at the rate of about eleven kilometres per hour. By the help of the rudder considerable deviations were made, both to the right and to the left of the wind's course.—*Comptes Rendus*, Oct. 15, 1883. C.

Observations on the Pic du Midi.—Thollon and Trepied have made some special observations on the Pic du Midi, preparatory to the proposed establishment of an astronomical observatory. The height is sufficient to reduce the thickness of the atmospheric screen by about one-third, the portion which is left below being the one which contains the greatest amount of mist, vapor and dust. By masking the sun with an elongated screen they were able to see Venus, by the naked eye, when within two degrees of the solar disc. The disc often had a sharpness and steadiness such as they had never observed elsewhere, at Nice, in Italy, in Algeria, or even in Upper Egypt. The solar spectrum often appeared crossed, through its whole length, by a considerable number of fine striæ, some brilliant and others obscure, which they could attribute to nothing else than granulations of the photosphere. The hydrogen lines C and F were not continuous, but formed of distinct fragments, of the same order of magnitude as the intervals of the striæ, showing conclusively that the chromosphere offers a system of granulations analogous to that of the photosphere. The two systems are separated in the spectroscope, one giving a continuous spectrum and the other a spectrum of lines. They are blended and confounded in a telescope or in a photograph. It is well known that there are eight brilliant lines in the chromosphere, visible under ordinary circumstances. On the Pic, during the five days on which observations could be made at a favorable hour, the number of lines was increased to over thirty, in the portion of the spectrum which is comprised between D and F, thus giving results very similar to those which are obtained during a total eclipse.—*Comptes Rendus*, Oct. 15, 1883. C.

Aurora Borealis at Behring Strait.—Nordenskjold has published his observations of the aurora borealis on the *Vega*, during the winter of 1878–9. They lead him to conclude that even during the years of least auroral intensity, the globe is surrounded by a luminous corona, which is nearly constant, and which may be simple, double, or multiple. While the *Vega* was in its winter quarters the corona was usually at a height of ·03 of the earth's semi-diameter (119 miles), and the centre coincided with a point below the surface and a little north of the magnetic pole. The corona, with a diameter of about ·32 of the earth's radius (1,268 miles), extended in a plane, perpendicular to the radius which passes through its central point, thus indicating that its height above the surface of the globe is everywhere uniform. The outline is nearly circular, with slight oscillations in the diameter of the circle, and even in the position of its centre; but in magnetic storms the changes may be rapid and considerable. After repeated observations with the polariscope, there was a universal conviction that the light had no appreciable polarization. The whole paper is one of the most interesting that has ever been published upon the subject.—*Ann. de Chim. et de Phys.*, Jan., 1884. C.

History of Brass.—Pliny speaks of calamine as being produced in melting furnaces when zinc ores were used. According to Aristotle, the people living in the neighborhood of the Black Sea used calamine in order to give copper a beautiful gold color. The alloy of copper and zinc had no special name among the Romans; it was considered only as a beautifully colored "*aes*." In the middle ages, the Greek name "oreichalkos," or mountain copper, was commonly used. The alchemists of the middle ages believed, like their predecessors, that the copper was simply colored by the calamine. Metallic zinc is first mentioned in the fifteenth century, by Paracelsus, but its relation to brass was not fully understood until a later date. The manufacture of brass was carried on especially in Flanders, Cologne, Nuremberg, Paris and Milan.—*Dingler's Journal*, Oct., 1883. C.

Slow Movements of the Soil.—Daubrée presented to the French Academy, with flattering encomiums, the work of Prof. A. Issel, of Genoa, on the Slow Oscillations of the Ground. Faye examines the question from the standpoint of Geodesy, and thinks the author is too ready to sacrifice the idea which has been sustained by Fourier, Cor-

dier and Elie de Beaumont, of the progressive cooling of the earth. In the beginning, when the planet was in a state of complete fusion, its exterior form, coinciding with its mathematical form, was that of an ellipsoid of revolution, flattened at the poles and turning around its smaller axis. To-day, after the slow oscillations of the soil have acted during millions of years, the globe, crumpled and deformed, presents on one hemisphere an accumulation of emerged continents, and on the other a solid crust, profoundly depressed and covered by water. In spite of these striking deformations and the alteration of the visible contours, the mathematical figure of the earth has remained an almost perfect ellipsoid of revolution, as at the beginning; the globe has not ceased to turn, in a stable manner, around its smaller axis, and the variation of weight from the equator to the poles has not undergone the slightest modification.—*Comptes Rendus*, Oct. 1, 1883. C.

Interpretation of Spectroscopic Phenomena.—Faye rejects, as fabulous, the velocities of 100 or 150 leagues per second, which seem to be indicated, at the sun's surface, by the prodigious rapidity with which the protuberances are formed, and the partial displacements which are observed in the hydrogen lines. Thollon contends, however, that the velocities which are indicated by each of these phenomena are quantities of the same order, and that their maximum value corresponds to the cometary velocities in the same region. Every movement of luminous matter, which approaches us or recedes from us, undoubtedly produces a displacement of spectral lines. No theory indicates, and no fact demonstrates, that any other cause is fitted for producing the same effect. It is, therefore, very natural to consider such displacement as an indication of movement.—*Comptes Rendus*, Oct. 1, 1883. C.

Semi-Incandescent Electric Lamp.—P. Tihon has exhibited to the Lyons Society of Industrial Science, a lamp in which he has sought to combine the intensity of the voltaic arc with the steadiness of the incandescent lamp. When the carbons are brought in contact, the resistance is almost destroyed and the light is fixed, but very feeble. It is, therefore, necessary to preserve the arc, in order to secure intensity, and for steadiness it is also necessary to give the current a solid pathway, instead of abandoning it to the medium of the atmosphere. In order to secure both of these ends, the inventor places a small prism of chalk vertically between two carbons, which are slightly

inclined against it at their upper extremities. The current raises the chalk to a temperature similar to that of the arc itself, and increases the conductibility sufficiently to maintain the arc and avoid sudden extinctions. The incandescence of the chalk cannot vary so rapidly as the current, so that the prism serves as a fly-wheel, absorbing the heat of the arc, transforming it into light by its own incandescence, and distributing the light with great regularity.—*Les Mondes*, September 8, 1883. C.

Applications of the Phonic Wheel.—Du Moncel describes numerous useful applications of the phonic wheel, especially in measurements of time. Various chronographs have been devised for measuring very small intervals of time, which occur between different phases of every phenomenon which one may wish to study. In order to obtain such measurements it is essential to have a perfectly uniform movement on the part of the motor which is called upon to furnish the indications. The phonic wheel resolves this problem precisely and in the most simple manner. M. Lacour says that if we calculate the limit of error which can result from this system of measurement we shall find that it is less than $\frac{1}{250}$ of one per cent. The mode of action of the phonic wheel makes it applicable to clockwork in some cases. In fact, as three systems of apparatus concur in its operation and as these systems can be placed at any desired distance apart, the vibrating apparatus may be arranged under such conditions that the external causes which act upon chronometers will be controlled, and then the counting apparatus which is directed by the phonic wheel will furnish indications rigorously exact, in any convenient place. Since many phonic wheels can be introduced in the same circuit we can have many clocks, with movements which are altogether synchronous. The seconds' hand, or any other which moves still more rapidly, can accomplish its revolution without shock and in a manner which is perfectly regular.—*La Lum. Electrique*, April 21, 1883.

Arsenic in Wines.—A wine merchant, having received complaints of his wines, asked Barthélemy to make an analysis, which resulted in the discovery of considerable quantities of arsenic. Upon inquiry, it was found that the proprietor was in the habit of cleaning his casks with dilute sulphuric acid, which is very apt to contain arsenic. That this was the source of the difficulty was shown by examining the wine in new casks, and finding that it was free from poison.—*Comptes Rendus*, Oct. 1, 1883. C.

Waterproof Clothing.—In order to remedy the inconveniences to which soldiers are exposed in stormy weather, the Belgian government proposes to make their clothing perfectly waterproof. The experiments at Vilvorde have satisfied physicians that cloths, which are prepared with a salt of aluminum, do not hinder cutaneous respiration, and chemical analysis shows that they lose neither their quality nor their color. More than 10,000 yards of cloth, after having been subjected to repeated severe washings and tests of different kinds, preserved their impermeability until the threads were worn completely through. The greatest objection to the process is its cost, A suitable acetate of aluminum is obtained by preparing separate solutions of alum and acetate of lead. When these solutions are mixed the lead is precipitated in the form of a sulphate.—*Les Mondes*, September 1, 1883. C.

Franklin Institute.

[*Proceedings of the Stated Meeting, held May* 21, 1884.]

HALL OF THE INSTITUTE, May 21, 1884.

Mr. William P. Tatham, President, in the chair. Present 132 members.

The minutes of the April meeting of the INSTITUTE, of the Board of Managers and of the various standing committees were reported and approved. 16 persons were reported to have been elected to membership at the last meeting of the Board.

The paper for the evening, "To Chicago in Seventeen Hours," by W. Barnet Le Van, in the absence of the author, was read by the Secretary. It was discussed by Messrs. Hugo Bilgram, Cyrus Chambers, Jr., and J. W. Nystrom. The paper with the discussion thereon has been referred to the Committee on Publication.

A description, illustrated with perspective and sectional lantern views, of the Master Crusher and Pulverizing Mill was read for Mr. C. Henry Roney, by the Secretary.

The Secretary's report embraced remarks on the possibility of utilizing certain wasted natural forces, and in connection therewith, an illustration of, and remarks on Captain John Ericcson's Solar Engine; the present position of the Tehuantepec Ship Railway Project of Capt. Jas. B. Eads; and on the Water Gas Controversy in Massachusetts. The following mechanical inventions were also shown and described. The System of Balancing Machinery devised by the Defiance Machine Works

of Defiance, Ohio, a handsome working model of which was presented to the INSTITUTE by the Company. Diefendorfer's Anti-friction Bearing. A Measuring Machine (four inches capacity) devised by Prof. J. E. Sweet, and manufactured by the Syracuse Twist Drill Company of Syracuse, N. Y. An Automatic Nut for Vehicle Axles, invented by Mr. A. Anderson, of Goltz, Md., and a Nut Lock, invented by Thomas Curry, of Philadelphia.

A photographic view of a series of gun and pistol barrels, which had been burst by firing the same when obstructed by "stuck" bullets, wet sand, mud, etc., was shown on behalf of Mr. William McK. Heath.

Mr. G. M. Eldridge offered the following preamble and resolution, which after some debate were adopted, viz:

"WHEREAS, The forthcoming International Electrical Exhibition of the FRANKLIN INSTITUTE will present a school of instruction in electrical science unparalleled in America; and

"WHEREAS, It is desirable that the youth of this city should have a full enjoyment of the benefits thus offered; therefore,

"*Resolved*, That the Board of Education of the City of Philadelphia be requested to make an order that the scholars at all the grammar schools and high schools, who may desire to visit the Electrical Exhibition, may do so under the charge of their teachers, as a substitute for a school session on days to be fixed by the Board."

Mr. J. W. Nystrom offered some objections to the results of the tests of the model of the Gaffney boiler, as reported at a previous meeting by Mr. S. Lloyd Wiegand.

Adjourned.

WILLIAM H. WAHL, *Secretary.*

Annual Report of the Director of the Drawing School of the Franklin Institute for the Sessions 1882–1883.

The progress of the Drawing School for the year which ends this evening, has been very satisfactory. The methods of instruction have been improved, the facilities increased, and an advance made in every particular. Much of the work done by the pupils will bear a critical examination as to the thought and study involved and as to the execution. The specimens exhibited this evening illustrate the system of instruction. Those from the Junior Mechanical Classes show a thorough course in Plane Geometry, and an introduction to the principles

of Projection. This gives the student a familiarity with the names and forms of the principal lines, shapes and magnitudes, with which he has to deal, teaches him graphical methods of solving problems, impresses upon him the importance of care and accuracy, and, at the same time, initiates him into good form as regards using his implements. These classes have been in charge of Mr. George S. Willits.

The drawings from the Intermediate Mechanical Classes give an idea of the importance we place upon a thorough knowledge of Projections. A careful examination of them will show many intricate problems, which would puzzle the most expert; and, it must be admitted, that a student, who has obtained a clear understanding of them, is well prepared for any difficulties that may occur in actual work. Particular care is taken with this branch of the subject, because it is the fundamental basis of mechanical drawing, and, at the same time, is not properly understood and appreciated by draughtsmen generally. These classes have been in charge of Mr. Carl Barth.

The drawings from the Senior Mechanical Class show the application of the principles learned in the other classes to the making of working drawings of machinery. In this class, some complete machine of an interesting nature and good design is taken as a study, its use, operation and construction explained, and the class is required to make detailed drawings of it, to scale, after the manner of our best draughting offices, special attention being given to accurate measurements, the proper use and distribution of dimension lines and figures, the employment of sections and shade lines, and all the technicalities of mechanical drawing. This class has been in charge of the Director.

In the Architectural Class considerable original work has been done and some designs made which are intended for actual construction. The making of plans and elevations of buildings, and details of interior and ornamental work, are the features of this class, which has been in charge of Mr. Edward S. Paxson.

The drawings from the Free-Hand Class show marked improvement this year. This is due in great measure to the better facilities and to the additions made to the collection of casts. In this class, the student first draws from flat copies graded according to his skill, and afterwards from casts, commencing with simple geometrical figures and advancing up to the human form. This class has been in charge of Mr. Edward S. Paxson.

The following students deserve honorable mention for the interest

they have taken, the regularity of their attendance, and the superiority of their work:

In the Senior Mechanical Class.—Willis H. Groat, John S. Wilson, James G. Davis, Miss E. J. Longstreth, Harry P. Ewen, John Way Atkins, Alphonso E. Kirschner.

In the Intermediate Mechanical Classes.—Hugo L. Hund, M. Uhlmann, James M. Cox, Jr., J. Herbick, V. Forbensen, Frank Zimmermann, Benjamin W. Rees.

In the Junior Mechanical Classes.—A. H. Lea, Joseph Trottman, Miss Mary J. Colwell, Elwood M. Rowand, James C. Biddle, Jr.

In the Architectural Class.—Thomas Shenton, George F. Jackson, James J. Allen.

Drawing from Casts.—Thomas Eagan, A. M. Chandler.

In Free-Hand Drawing.—John Walbold, James Dunn, George Highley, John Dueringer.

The following students, at the close of the Winter Term, received scholarships from the B. H. Bartol Fund, entitling them to free attendance during the Spring Term:

Willis H. Groat, Miss E. J. Longstreth, John Way Atkins, James G. Davis, Charles von Berger, Joseph Edel, Hugo L. Hund, C. W. Regester, J. E. Pugh, William Kinhead, Charles Fleming, E. Kolb.

The following students, having completed a full course of four terms, are awarded certificates to that effect:

In Mechanical Drawing.—Harry P. Ewen, Alphonso E. Kirschner, James T. Baker, M. Morgan, Henry M. Lutz, John F. Abbott, Alphonsus Jones, Frederick Weyman, Isaac C. Mercer, Frederick Kalesse, Otto W. Manz, William Newbigging, Charles A. Eimert.

In Architectural Drawing.—George F. Jackson, James J. Allen, John Dueringer, Frederick O'Neill, William F. Cook.

In Free-Hand Drawing.—Edward A. Miller, Frederick Reutlinger, Charles Fleming, W. H. Pabst.

The following students are awarded Free Scholarships for the next term, beginning September 30, 1884:

Miss E. J. Longstreth, M. Uhlmann, A. H. Lea, Joseph Trottman, James J. Allen, Thomas Eagan.

They will present themselves to the Actuary at that time and receive their tickets.

WILLIAM H. THORNE,
Director.

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(Concluded from page 399.)

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